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Final Report On

HYBRIDIZATION OF BIOMEDICAL CIRCUITRY

December 20, 1978



UNIVERSITY OF DENVER • DENVER RESEARCH INSTITUTE

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ABSTRACT

The report gives the results of the design and fabrication of low power hybrid circuits to perform vital signs monitoring. The circuits consist of:

1. Clock, 2. ECG Amplifier and Cardiotachometer signal conditioner, 3. Impedance Pneumograph and respiration Rate Processor, 4. Heart/Breath Rate Processor, 5. Temperature Monitor and 6. LCD Display.

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Summary

The project was to hybridize a set of vital signs monitoring circuits. The circuits were evaluated and found unsuitable for hybridization in their present form. The circuits were redesigned and fabricated. In addition a breadboard with LCD display was designed and fabricated. The new designs were considered to be so novel as to be patentable.

Recommendations

The hybrid circuits and their conventional counterparts are present state of the art devices. They also require considerable less power than previous circuits. They constitute the basis for any vital signs monitoring system. In particular in the hybrid form they can be integrated into a small hand held device for hospital or similar use.

I. INTRODUCTION

The objective of the project was to design and build 10 each hybrid electronic circuits to duplicate the function of 10 individual circuits, the diagrams of which were provided by NASA.

The circuits provided were not suitable for hybridization and represented technology at least 10 years old. Therefore the circuits were designed using a hybrid philosophy and present day technology. The circuit functions are described below as well as the resultant circuits. In addition to the hybrid circuits, a breadboard display system was also designed and fabricated.

The circuits and configurations illustrated in the drawings and figures listed have been submitted for patent coverage and the University has obtained Waivers of Domestic and Foreign Rights under contract number NAS 9-15206, effective 31 October 1978, as follows:

Title	Dwg./Fig. <u>Number</u>	Waiver <u>Number</u>	Case <u>Number</u>
Vital Signs Monitor	Figure 9	W-1957	MSC-18232
All below	Figure 6	All below	All below
Temperature Monitor	EC-13269	W-1956	MSC-18231
ECG Amplifier and Cardiotachometer Signal Conditioner	EC-13257	W-1955	MSC-18230
LCD Driver	EC-13299	W-1954	MSC-18229
Clock	EC-13159	W-1953	MSC-18228
Heart/Breath Rate Processor	EC-13157	W-1952	MSC-18227
Impedance Pneumograph and Respiration Rate Conditioner	EC-13268	W-1951	MSC-18226

II. CIRCUIT FUNCTION

The circuit diagrams provided by NASA as guides are given in Appendix A. This does not include the blood pressure circuit which was deleted from the contractual requirements. The functions of the circuits are:

- Body thermometer
- Heart Beat Detector
- Heart Rate Processor
- Respiration Rate Processor
- Impedance Pneumograph
- ECG/EEG/EMG Preamplifier

The specifications for the circuits are given in Table 1.

TABLE 1.

Vital Signs Circuits Specifications

Thermometer Specifications

Output Linearity	Within 1 percent of a straight line
Stability	+5% supply voltage step shall not change output indication
Range	80 to 110°F
Response Time	40 seconds to indicate 98.5% of final value following a 2.8°C equivalent input step
Analog Output Impedance	200 Ω max (resistive)
Probe Characteristics	10K Ω input equivalent to 25°C
Analog Output Level	+2.5 V

Heart Beat Detector Specifications

Input	Shall accept the analog output from the ECG preamplifier
Output Impedance	10K Ω max

Heart Rate Processor Specifications

Range	40 to 200 beats per minute
Overall Accuracy	At least $\pm 2\%$ + one beat of full range
Output Bases	Output #1 shall be on a beat-to-beat basis Output #2 shall be based upon five consecutive periods between the heart pulses which determine the periods. The output data shall be updated every 5 heart pulse periods.

Respiration Rate Processor Specifications

Range	6 to 24 breaths per minute
Overall accuracy	At least $\pm 2\%$ + one breath of full range

Impedance Pneumograph (Respiration Preprocessor) Specifications

Input Excitation	Current provided shall be 0.5 ma max at 50 ± 5 kHz looking into subject impedances ranging from 100 to 1000 ohms.
Input Impedance	10K ohms min. at 50 kHz and 10M ohms min. over 0 to 100 Hz range (when connected to subject impedance)
Input Circuit	Compatible with ECG input circuit hooked in parallel. True differential.
Frequency Response	-3db at 10 ± 1 Hz. Minimum eventual roll-off of -6db/octave.

ECG/EEG/EMG Preamplifier Specifications

Input Impedance	40M Ω min differential and each side to ground
DC Offset	Able to withstand ± 0.25 VDC differentially input
Input Circuit	True differential 0.5 μ a max input lead current under any operating conditions. Compatible with 50 kHz ± 5 kHz across input leads

Source Impedance	1 to 100K ohms
Source Unbalance	1 to 100K ohms in either input lead
Analog Output Level	<u>+2.5</u> volts
Impedance	200 Ω max (resistive)
Frequency Response	+0.5db from 0.14 Hz to 70 Hz -3db at 0.05 Hz and 100 Hz
Harmonic Distortion	Less than 1%
Recovery Time	24 sec from 2 volt input pulse
Common Mode Rejection	90 db min w/shorted input
Output Noise	10 μ v p-p referred to input
Gain Range	600 to 4500 continuously variable
Stability	Able to tolerate <u>+1%</u> power voltage step
Ripple	-80db @ 100mv 8 to 15 kHz on power input

III. CIRCUIT DEVELOPMENT

It was decided that the vital signs functions could best be provided by the following collection of individual circuits:

Clock - to provide all control frequencies required by the other hybrid circuits

ECG Amplifier and Cardiometer Signal Conditioner

Impedance Pneumograph and Respiration Rate Signal Conditioner

Heart/Breath Rate Processor

Temperature Monitor

LCD Driver - to provide Liquid crystal display capability

These circuits are described below. Schematics for all these circuits are given in Appendix B.

1. Clock

The clock circuit provides the required frequencies for the digital processing of all vital signs data. Figure 1 is a block diagram for this circuit which depicts its operation. Oscillator H_1 is a crystal-controlled oscillator which provides the $100 \text{ kHz} \pm 0.01\%$ output through Buffer Driver #1. This portion of the circuitry was designed to accept an external Reeves-Hoffman RH-170 crystal which exhibits small physical dimensions. A total of nine dividers exist in this circuitry to form the required frequencies and the proper dividers to obtain them are illustrated in Figure 1. The only additional circuitry consists of buffer drivers for the frequencies might be used by several of the remaining circuits of the Vital Signs System. Only one clock circuit is required for any configuration of the vital signs display system. The schematic for the clock circuit is EC-13159.

The oscillator frequency is $100 \text{ kHz} \pm 0.01\%$. The other frequencies outputs provided are:

50 Hz, 6.25 kHz, 1 kHz,
166.6 Hz, 33.3 Hz, 25 Hz,
10 Hz and 8.3 Hz

The clock provides necessary signals to the following circuits:

Heart/Breath Rate Processor (13157)

Temperature Monitor (13269)

L.C.D. Display Driver (13299)

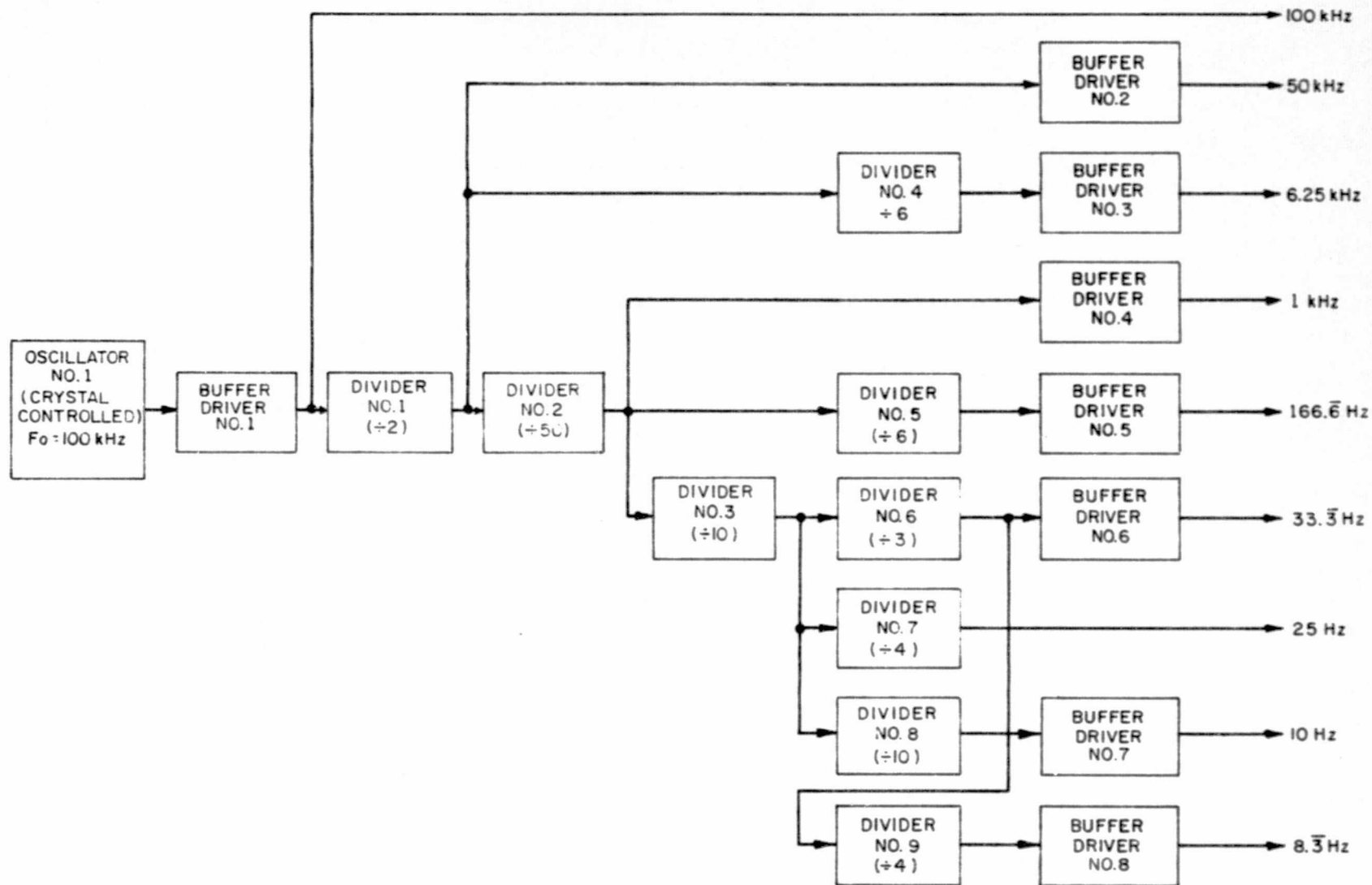


FIGURE 1. BLOCK DIAGRAM OF CLOCK CIRCUIT.

2. ECG Amplifier and Cardiometer Signal Conditioner

This circuit receives the heart signal from three electrodes one of which is the common or reference electrode. The heart signal is first amplified by a balanced differential amplifier with very high input impedance and large common mode rejection. The heart signal is then fed to a bandpass filter to suppress unwanted noise and interference. An amplifier with adjustable gain provides the low output impedance necessary to form the ECG output from the heart signal.

The filtered heart signal after additional filtering is fed to a normalizing circuit which standardizes the amplitude of the pulse regardless of polarity. A bipolar threshold circuit is used to detect the time of occurrence of the QRS pulse. The threshold output pulse is then standardized in width and amplitude for use by the heart rate processor.

The first consideration whenever a hybrid circuit is designed must be to reduce power dissipation and component physical size as much as possible within reason. The input differential amplifier consists of three operational amplifiers contained on one chip. The quiescent current is adjustable by means of a set resistor and have been adjusted to approximately 15 microamps each. This is possible since the bandwidth required is very modest which also ensures input impedance well above the required 40 megohms differential and common mode. Because the input circuit is identical for both differential and common mode signals the amplifier is truly balanced. The input pair also possess the unique property that the gain for differential signals is +40db, whereas common mode signals receive only unity gain. Thus the final amplifier in this group of three which connected as a standard difference amplifier, need only contribute 50 db to the CMRR since the input pair supplies 40 db of the required 90 db total.

Referring to schematic #EC-13257, C3 and R11 determine the low frequency cutoff of .05 Hz for the heart signal. To ensure that C3 is of reasonable physical size, R11 must be very high resistance. The operational amplifier U2 must be selected for low offset current as well as low quiescent power dissipation. The selected type MLM108 exhibits input offset of 0.4 nanoamps maximum, and power supply current of only 300 microamps typical. Output offset voltage at U2 will thus be $0.4 \times 10^{-9} \times 6.8 \times 10^6 = 2.7$ millivolts maximum. U7 is the ECG output amplifier with gain adjustable from 6.25 to 48. At maximum gain the d.c. offset at the ECG output will not exceed $2.7 \times 10^{-3} \times 48 = 0.125$ volts.

U8 and associated circuitry constitute a high impedance active bandpass filter with low output impedance. The filter center frequency is 17 Hertz with $Q=3$. This filter prevents cardiometer triggering on abnormally large T wave. The final unique feature of this module is the normalizing of the filtered ECG signal. U3 is a high gain amplifier whereby FET Q1 becomes a variable shunt attenuator controlling the overall gain. The output of amplifier U3 and inverter U4A are full wave peak detected by means of D1, D2, and C9. Thus the maximum peak amplitude regardless of polarity is stored on C9 and transferred to the output of the voltage follower U5. The summing amplifier U4B combines the above mentioned peak detector output with a portion of the original filtered ECG signal to linearize the FET voltage characteristic. R52 is selected to get d.c. operating voltage at the FET gate thereby calibrating the normalized output

at pin 6 of U3 at 2 volts peak. U4C is merely an inverter which drives the FET gate. Therefore, the largest peak of the filtered ECG signal will become 2 volts peak regardless of input amplitude over the specified range. Thus the bipolar threshold circuit consisting of U6A, B and C biased at plus and minus 1.5 volts, reacts whenever the normalized signal exceeds this value either positive or negative.

This circuit was designed to be used in the vital signs system. However, it can be used separately with other ECG Display (strip charts or oscilloscopes) or as an input to a cardiometer circuit.

3. Impedance Pneumograph and Respiration Rate Signal Conditioner

This circuit measures the change in impedance at 50 kHz of the chest as it expands and contracts during the breathing cycle. The same electrodes as used for the heart signal are simultaneously driven with balanced 50 kHz current. The balanced voltage developed across the chest impedance is first amplified and then rectified since the breathing cycle acts as amplitude modulation for the 50 kHz signal. A simple bandpass filter is used to remove undesirable noise which occurs beyond the required passband. After additional gain the breath signal has been formed into the impedance pneumograph signal.

The impedance pneumograph signal is also subjected to an additional low pass filter followed by a balanced d.c. restorer. A threshold circuit with hysteresis is followed by an output circuit which standardizes the amplitude for use by the breath rate processor.

The impedance pneumograph depends upon the change in impedance across the chest as breathing takes place. It is necessary to provide balanced (with respect to the common electrode) constant current at 50 kHz not exceeding 500 microamps peak. Another specification requires that the isolation at 0 to 100 Hz must exceed 10 megohms, but may be as low as 10 kilohms at 50 kHz. The solution selected utilizes C3 and C5 to supply balanced current to the subject as shown on schematic #EC-13268. Since the chest impedance is very nearly resistive, the excitation circuit acts as a differentiator, which limits the excitation voltage waveshape that can be used. Ideally a squarewave of current would produce the largest rectified d.c. voltage across the chest resistance for a given peak current. The integral of a squarewave is a triangular wave which is the waveshape used in this circuit. U1 is a 50 kHz triangular wave generator which is due to the slew rate limitation adjustable by C2. U2 is merely an inverter which produces an opposite polarity waveform of equal amplitude. The excitation generator output voltage is very nearly 18 volts peak to peak which is the total supply voltage. C3 and C5 are both 120 pf which produce a reactance of 25 ohms at 50 kHz and greater than 13 megohms at 100 Hz. The peak current can be calculated as follows if we neglect the chest resistance which is small compared to the capacitive reactance of C3 in series with C5.

C3 and C5 in series = $120 \text{ pf} \div 2 = 60 \text{ pf}$. The balanced excitation voltage slope is:

$$\frac{18 \text{ volts} \times 2}{10 \mu\text{s}} \text{ or } 3.6 \text{ volts}/\mu\text{s}$$

then:

$$\frac{Q_p}{t} = \frac{CE}{t} = 60 \times 10^{-12} \text{ farads} \times 3.6 \text{ volts}/\mu\text{s} = 216 \times 10^{-12} \text{ coulombs}/\mu\text{s}$$

or

$$216 \times 10^{-6} \text{ coulombs/sec} = 216 \text{ microamps peak}$$

U3 and U4 comprise a balanced differential amplifier with reasonably high input impedance and wide bandwidth. The 50 kHz voltage drop across the chest impedance is coupled into the differential amplifier by means of C6 and C7, amplified and finally peak to peak rectified at the input to U5A.

The slowly varying voltage in accordance with the respiration rate is coupled into the voltage follower U6 by means of C16 and R16 which set the lower 3 db frequency at 0.1 Hz. U8C amplifies the respiration signal with a gain of 200, and also sets the upper 3 db frequency at 10 Hz by means C16. The output of U8C is available as the impedance pneumograph wave.

The impedance across the chest changes greatly as the subject moves and generates large signals which tend to mask the respiration signal. It is thus necessary to incorporate some techniques in the respiration rate pulse generating circuitry to discriminate against unwanted signals. The first technique incorporated an active 2nd order low pass filter with cutoff frequency at 1 Hz which reduces the active bandwidth from two decades (0.1 Hz - 10 Hz) down to one decade. This filter is comprised of U5C and associated resistors and capacitors. The second technique involves the use of a bipolar d.c. restorer with rather soft limiting characteristic. This circuit consisting of U7 and associated diodes, resistors, and capacitors, greatly reduces the recovery time when a large extraneous signal is present.

U8A is merely a threshold circuit with some hysteresis which converts the respiration signal into a squarewave. U8B is used to translate the squarewave voltage from 0 to +9 volts as required by the rate processor circuit.

The circuit was designed to be used in the vital signs system. However, it can be used separately as an impedance pneumograph or with other respiration rate processors.

4. Heart/Breath Rate Processor

Figure 2 is a block diagram for this circuit which depicts the operation of the circuitry. Counter #1 is an edge triggered counter which counts the number of heart/breath pulses. The output of this counter is active whenever one pulse or 5 pulses have been counted (selected by the one beat/five beats elect line). Switch #1 is used to transfer either of these two signals to Counter #2. Switch #2 works in conjunction with Switch #1 to supply the correct frequency to the remaining circuitry for the one beat or five beat computation mode. The breath rate, due to the time duration between breaths, is computed only on a breath-to-breath basis. The pulse transferred to Counter #2 is acted upon by initializing the remaining circuitry for the processing of a heart/breath rate based on the total count, N, accumulated in

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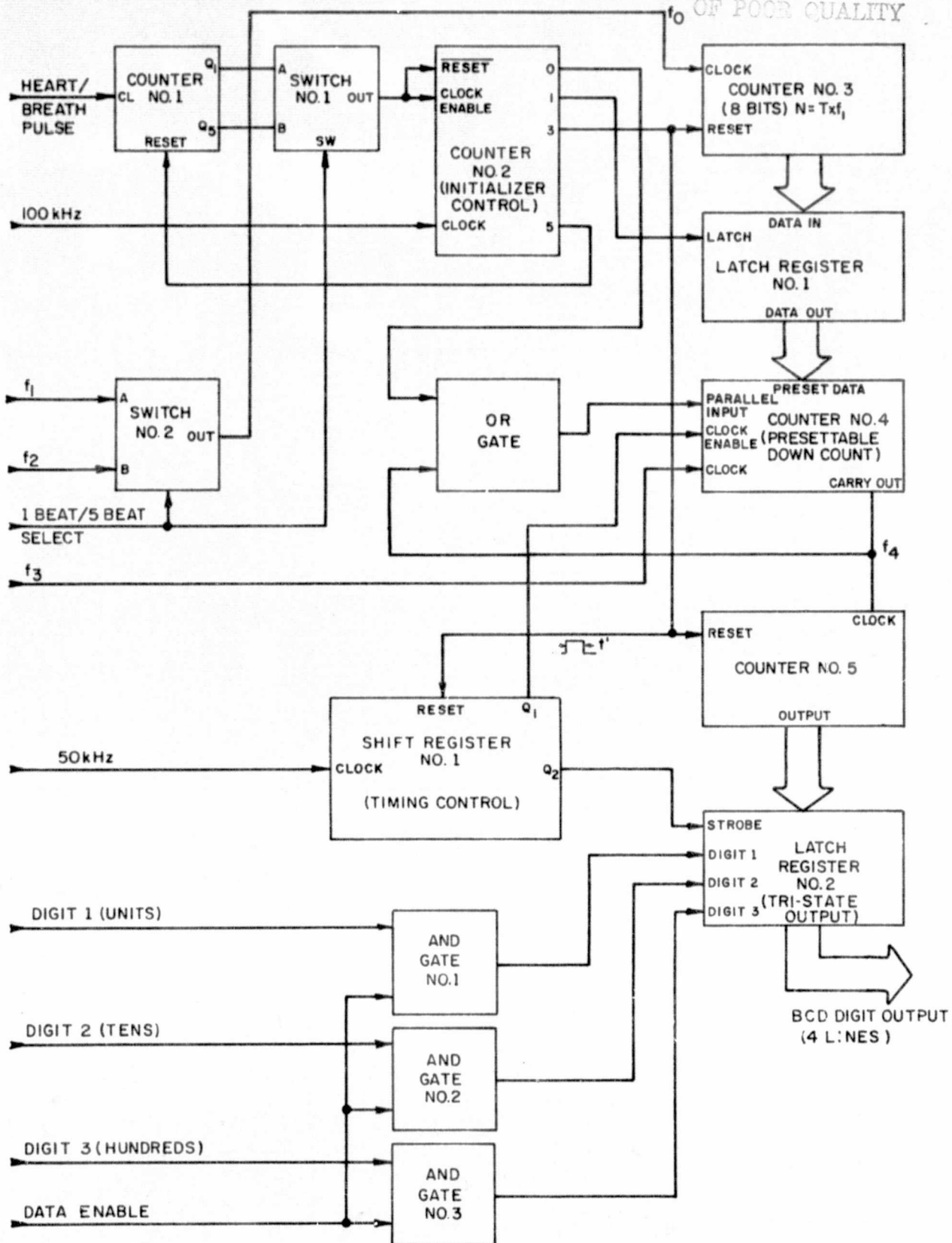


FIGURE 2. HEART RATE / RESPIRATION RATE PROCESSOR

Counter #3 between two successive pulses occurring at Counter #2. The count, N , equals the period between heart/breath (less than ten microseconds maximum, five microseconds minimum) times the frequency, f_1 , that is counted by Counter #3 for this period time.

The count, N , is then latched into Latch Register #i which is used as the preset into Counter #4, a presettable down counter. This count is preset into Counter #4 at the beginning of the processing and also whenever the counter has counted down to zero during the processing. The result of this action is that the Carry Out of Counter #4 is a frequency, f_5 , given by

$$f_5 = f_3 / N = f_3 / (T \times F_0); T = \text{heart/breath beat period in seconds};$$

$$f_3 = 50 \text{ kHz} \quad f_0 = 166.\bar{6} \text{ Hz for heart rate and } 33.\bar{3} \text{ Hz for respiration rate.}$$

Counter #5, which is a BCD counter with a count capacity of 199, counts the frequency, f_4 for a period of time, t^1 , which equals 0.2 seconds for heart rate and .12 seconds for respiration rate. This time period, t^1 , is generated by Shift Register #1 and a 10 Hz (heart rate) or 8.3 Hz (respiration rate) input frequency. At the end of t^1 Latch Register #2, which is a tri-state output latch register. This tri-state output allows all three digits to be wired together to form one 4-line BCD output. The Digit Output Enable lines are controlled by the display logic control via AND Gates #1, #2, and #3.

The resultant output count, R , that is displayed is equal to:

$$R = f \times t^1 = \frac{f_3 \times t^1}{N} = \frac{f_3 \times t^1}{f_0 \times T} = \frac{60 \text{ counts/second}}{T} = \frac{1 \text{ counts/minute}}{T}, \text{ where}$$

T has units of seconds.

The calculation of heart rate or breath rate is based on dividing the period of the event into a constant such that the result is equal to the rate in beats or breaths per minute. The above describes how this is done digitally.

The rate processor calculates heart rate from 40 to 200 beats per minute with an accuracy of one beat per minute. It calculates breath rate from 6 to 24 breaths per minute with an accuracy of one breath per minute.

In order to function the heart/breath rate processor must be provided suitable clock signals. In addition the pulses derived from an ECG Amplifier and Cardiometer Signal Conditioner or an Impedance Pneumograph and Breath Rate Signal Conditioner are required. If display is required, circuitry for this must be provided, however, the output is also suitable for telemetry or other data acquisition system.

5. Temperature Monitor

Figure 3 is a block diagram for the Temperature Monitor circuit depicting the operation of the circuit. The output voltage of operational amplifier #1 is equal to:

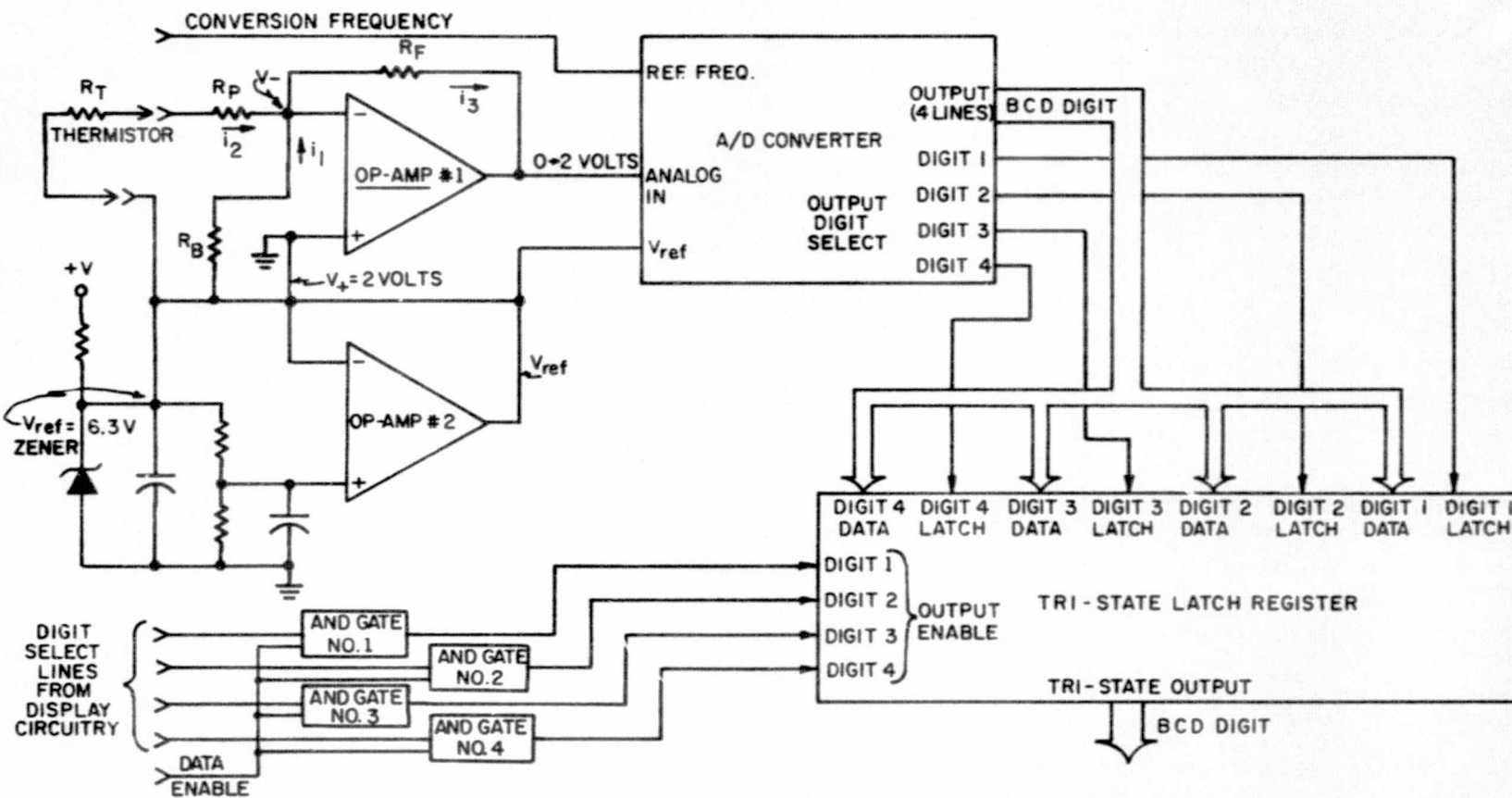


FIGURE 3. BLOCK DIAGRAM OF THERMOMETER SYSTEM

$$V_{out} = -V_{ref} R_F \left[\frac{1}{R_T + R_p} + \frac{1}{R_B} \right].$$

The zener diode and operational amplifier #2 form the voltage reference required for this technique for temperature computation. By using this reference voltage as the input to both operational amplifier #1 and the analog-digital converter, any changes in V_{ref} due to small changes in the power supply voltage minimizes the effect on the computed value of temperature. Resistors R_p and R_B are used to "linearize the thermistor," R_T , dependence on temperature. The values are chosen to minimize the error of V_{out} at 98.6°F or 37°C. A three point linearization of the thermistor's dependence of resistance to temperature curve is made at 32°C, 37°C and 42°C to produce this minimum error in the desired region of operation. This technique reduces errors in measured temperature to within one Count or 0.1°F. A part of this linearization process is the forming of V_{out} so that when converted by the analog-digital converter, the resultant digital output is a direct reading of temperature in degrees Fahrenheit.

The output of the analog-digital converter is multiplexed so that each of the four digits is presented at the same 4 bit output. The particular digit present at the output is indicated by the Output Digit Select lines which are used to latch the data into the appropriate location of the Tri-State Latch Register. The Tri-State outputs allow all four digits to be wired together to form one 4-line BCD output. The digit Output Enable lines are controlled by the display logic control via AND Gates #1, #2, #3, and #4.

The variation of a thermistor with temperature can be approximated by

$$R_T = \frac{a}{T-b} - p$$

where, T is temperature and a , b and p are determined to give a good agreement with the temperature-resistance curve.

This approximation allows a three point approximation to the thermistor's resistance curve by solving for a , b and p at selected temperatures.

Solving this equation for temperature gives

$$T = \frac{a}{R_T + p} + b$$

The output voltage of operational amplifier #1, in Figure 3 is

$$V_{out} = \frac{R_F}{R_T + R_p} + \frac{R_F}{R_B} V_{ref}$$

If we let:

$$a = K V_{ref} R_F$$

$$b = K V_{ref} (R_F / R_B) \quad \text{where: } K = 100^\circ\text{F/volt}$$

$$p = R_p$$

then

$$T = K V_{out}$$

As can be seen the temperature as indicated by the analog-digital converter does not depend on the actual reference voltage since the converter utilizes V_{ref} as a scaling factor in computing V_{out} . Therefore, the temperature reading is very nearly independent of supply voltage.

Sensitivities of the output voltage (temperature reading) as a function of component values were calculated to all be equal to or less than one for the circuit shown.

The Temperature Monitor Circuit can be adjusted to a given thermistor by selection of an external resistor in series with the feedback resistor (R_F is the series combination of these two resistors). This allows a 3% variation in temperature reading. Selecting the external resistor to 1% tolerance allows a calibration of the temperature to within 0.1%. Temperature readings are within a 1% of a straight line through this calibration point for the temperature range of 30°F to 110°F.

The Temperature Monitor is designed to be used with external clock and display circuits. The clock may be eliminated by utilizing a timing capacitor on the temperature monitors internal clock circuit. The circuit is also suitable for telemetry and data acquisition systems without the use of an external display.

6. LCD Driver

The data output circuitry of the vital signs function processors were designed in such a manner as to allow great flexibility in the display circuitry which will allow various combinations of vital signs functions other than those listed above to be assembled into any system configuration that is desirable. Figure 4 shows the general configuration of the data output circuitry to be used in all of the vital signs processors. The primary goal of such output configuration is two-fold, namely; 1) to reduce the number of interconnection lines required between the vital signs processors and the display system, and 2) to provide the flexibility required for several types of display systems. The first goal is realized by using "Tri-state output" latch registers and WIRE-ORing each level of the BCD data lines together so that only four BCD data lines need be outputted from each processor, and furthermore, by WIRE-ORing the four BCD data output lines of all the vital signs processors together so that only four inter-connection lines are required external to the processor packages to transfer all the data from the processors to the display system. With such a configuration, only one digit of information can be transferred at any given time. As such, a separate Digit Select line is required for each digit of BCD data to be displayed. This implies that for a display system which simultaneously displays all sixteen digits of the Vital Signs system as described above, twenty interconnection lines are required between the processors and the display system. In the remaining control line in the data output circuit configuration (as shown in Figure 4) is the Digit's Select Enable line which was added so that in conjunction with the other I/O data lines already discussed the second goal of flexibility would be realized. Finally, it should be noted that the data

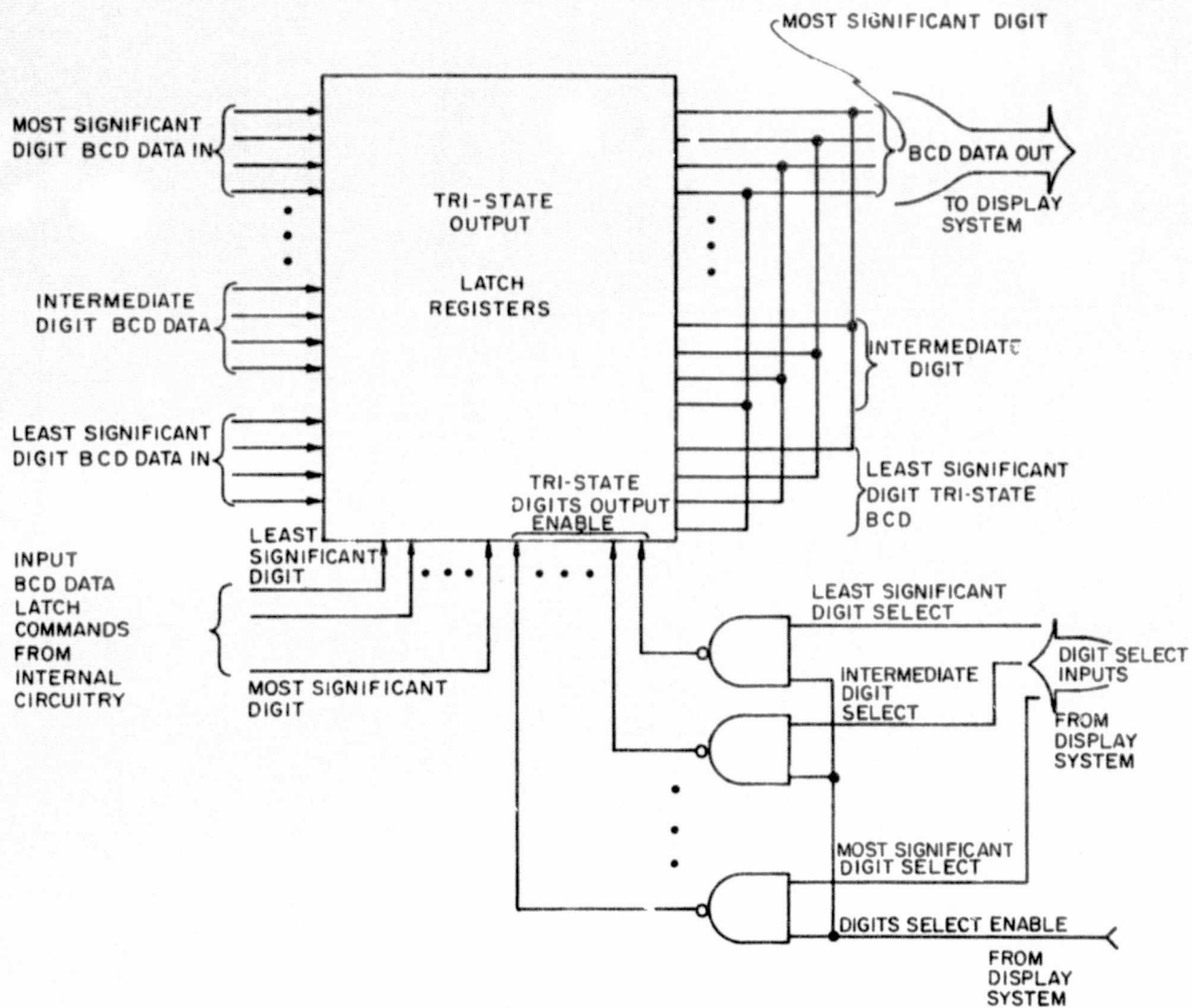


FIGURE 4. VITAL SIGNS PROCESSORS DATA OUTPUT CIRCUIT CONFIGURATION

I/O system being used exhibits the inherent flexibility that will more easily allow interfacing this data to parallel-to serial converters for transmission of data long distances over a single twisted-pair line and also will allow simple interfacing to a micro-processing or minicomputing system should such requirements ever arise at a later date.

While designing the display control circuitry, original attempts were made to design one hybrid package in such a way that one, or more, of the same type of package could be used by any display configuration desirable. It was soon discovered however, that due to the differences in control signals required for LED displays and LCD displays, any such hybrid package would be unnecessarily complicated, and that significant portions of the circuitry required for one type of display would be unused when the other type display is being controlled. This resulted in a shift of emphasis to that of designing two separate hybrid packages, where one package would be used to control LED displays and the second package would be used to control LCD displays. This approach soon led to the realization that the required display circuitry for LED displays was simple enough that hybridization of such circuitry was futile. The required combination of existing small-scale and medium scale integration circuitry in commercially available Dual-Inline packages is such that the miniaturization realized by hybridization would not be enough to consider the added expense of a specialized hybrid package worthwhile. This is especially true if an LED display is used which contains a latch register and BCD-to-seven segment decoder. Therefore, only a hybrid package for controlling an LCD display has been designed.

Refer to Schematic EC-13299 of the designed LCD Display Driver circuitry. This circuitry is capable of receiving and displaying three and one-half digits of data. This is the only hybrid package required for a four digit LCD. This circuitry also contains control functions to properly synchronize four such identical packages for controlling a sixteen digit LCD display. Therefore, the development of only one type of package is required. By far the most difficult display representation of those possible for the Vital Signs system is a sixteen digit LCD display. Figure 5 illustrates a block diagram for such a configuration. Notice in this diagram that the four Display Select Output lines of the LCD Display Driver #1 are used to synchronize all four drivers together so that only one digit of Vital Sign data will be placed on the BCD Data lines at one time. The Display Select Output lines of the remaining LCD Display Drivers are not used. Also, notice that the Digits Select Enable lines of each Vital Signs processor are not required for this display configuration so that they are simply wired to the system V+ bus lines. As a result, only twenty interconnect lines are required between the Vital Signs processors and the display circuitry. As the multiplex frequency sequences the divide-by-sixteen binary counters (Counter #1) in each of the LCD Display Drivers, one of four Display Select lines are active high as a result of decoding the most significant 2 bits of binary counter with the 1 of 4 Decoder #2. By routing the Display Select lines to each of the four LCD Display Drivers-Display Select In lines, one of the LCD Display Drivers has an active high Digit Select line corresponding to the count of the least significant 2 bits of the binary counter which is decoded with the 1 of 4 Decoder #1. The result of this action is that as the binary counter cycles through all possible 16 count states, each of the 16 Digit Select lines in the four LCD Driver packages are activated in turn. These Digit Select lines are routed to each of the Digit Select input lines of the Vital Signs processors, and to the strobe inputs of the BCD to LCD Display Decoders.

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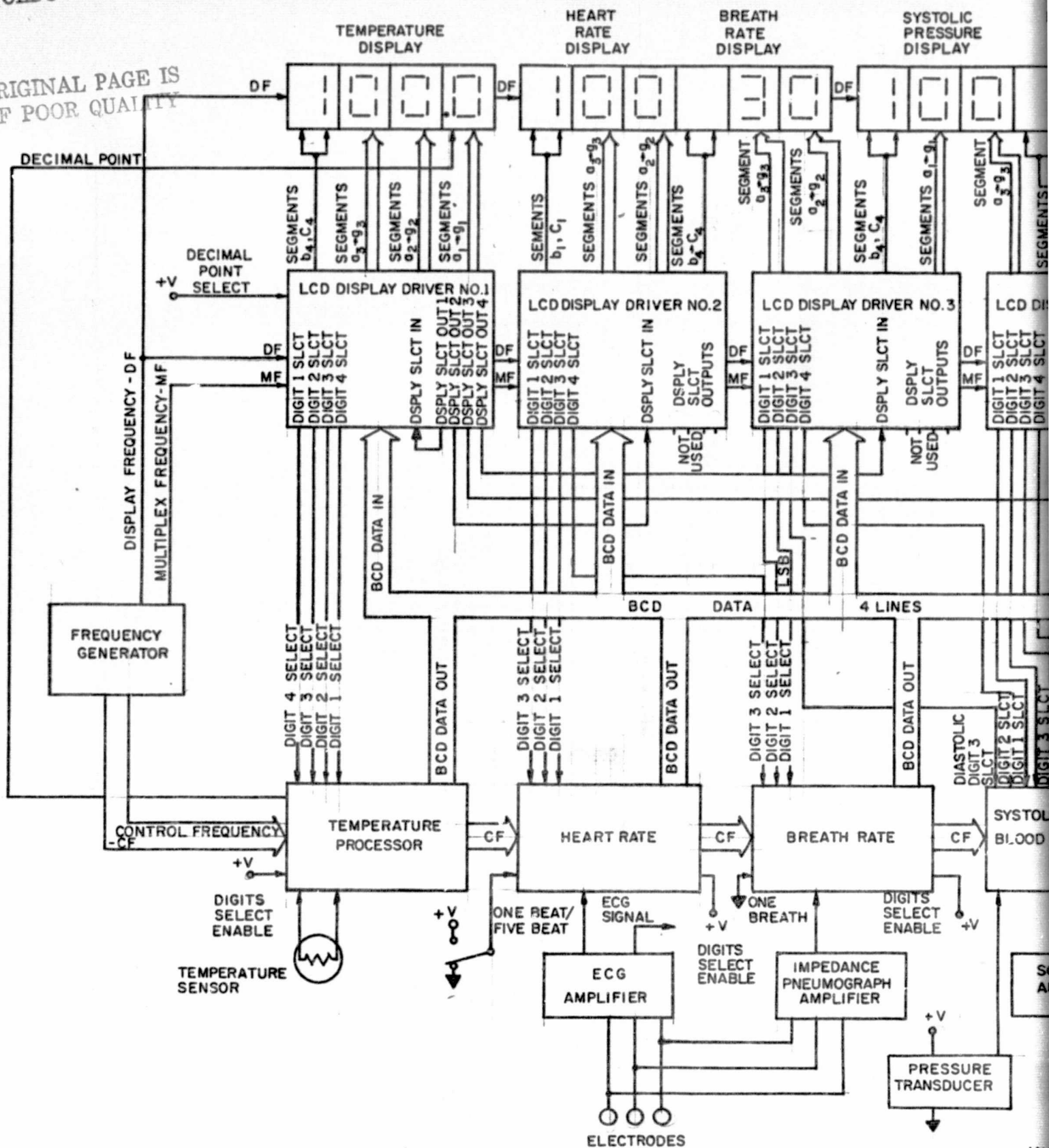
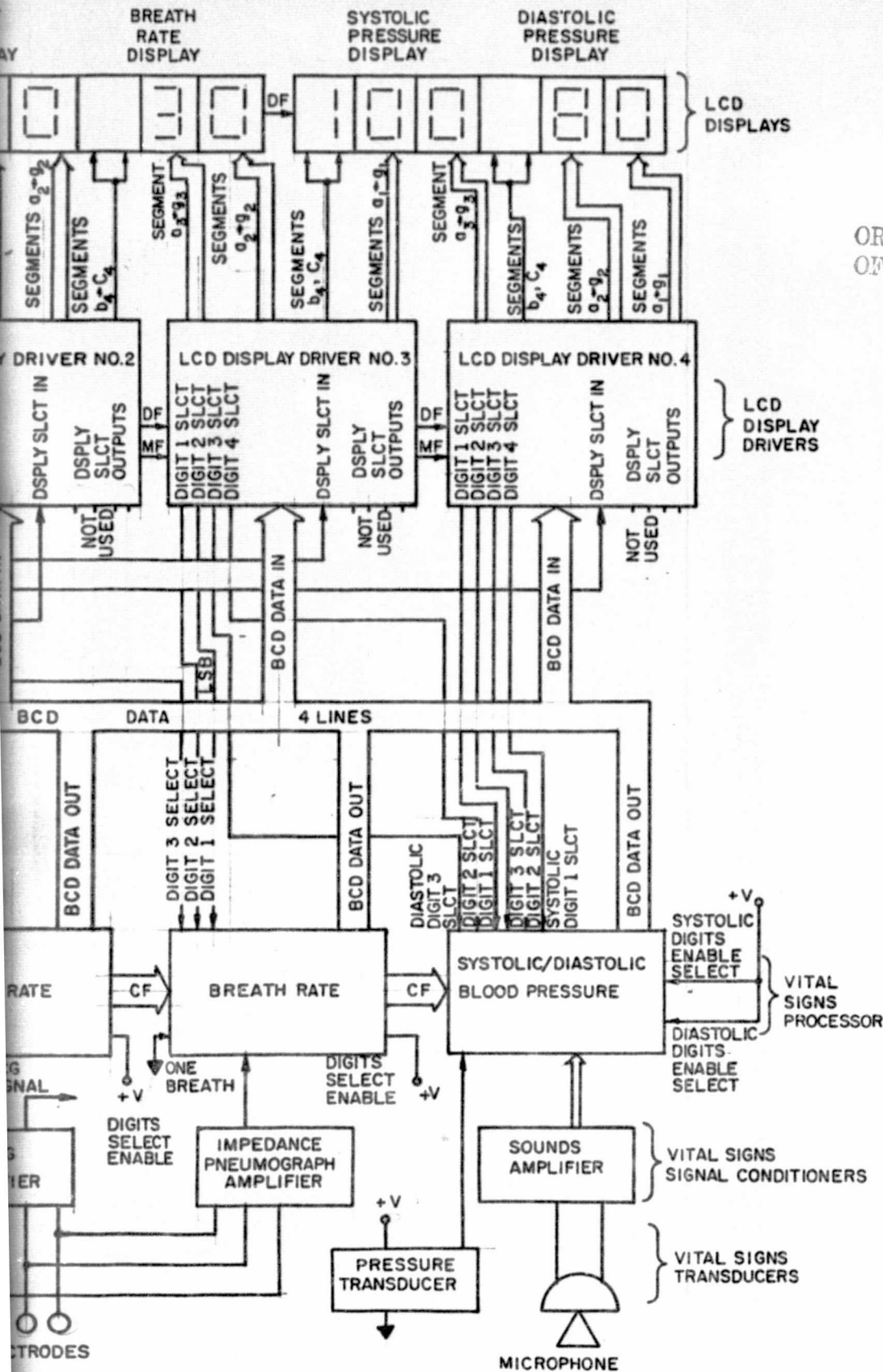


FIGURE 5. VITAL SIGNS SYSTEM DIAGRAM FOR 16 DIGIT LCD

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WIRING DIAGRAM FOR 16 DIGIT LCD

Thus, for every full cycle of the Counter #1 states, each of the 16 digits displayed are latched into the latch of the proper LCD display driver, and are in turn displayed at the proper LCD digit in the display.

The display driver is not intended to be operated as a unit, but only in conjunction with other circuitry. However, its flexibility allows its use in other data display system than the one for which it was designed.

IV. HYBRID CIRCUIT FABRICATION

All six (6) hybrid circuits were fabricated using standard thin film circuit technology.

The gold contact substrates were etched in a pattern that provided only circuit interconnections. No passive components were fabricated at this stage.

All active and passive components were attached to the substrate using conductive or non-conductive epoxy. The passive components were thick on thin film chip resistors or chip ceramic capacitors.

All remaining electrical connections were then made using a 1 mil ultrasonic gold ball wire bonder.

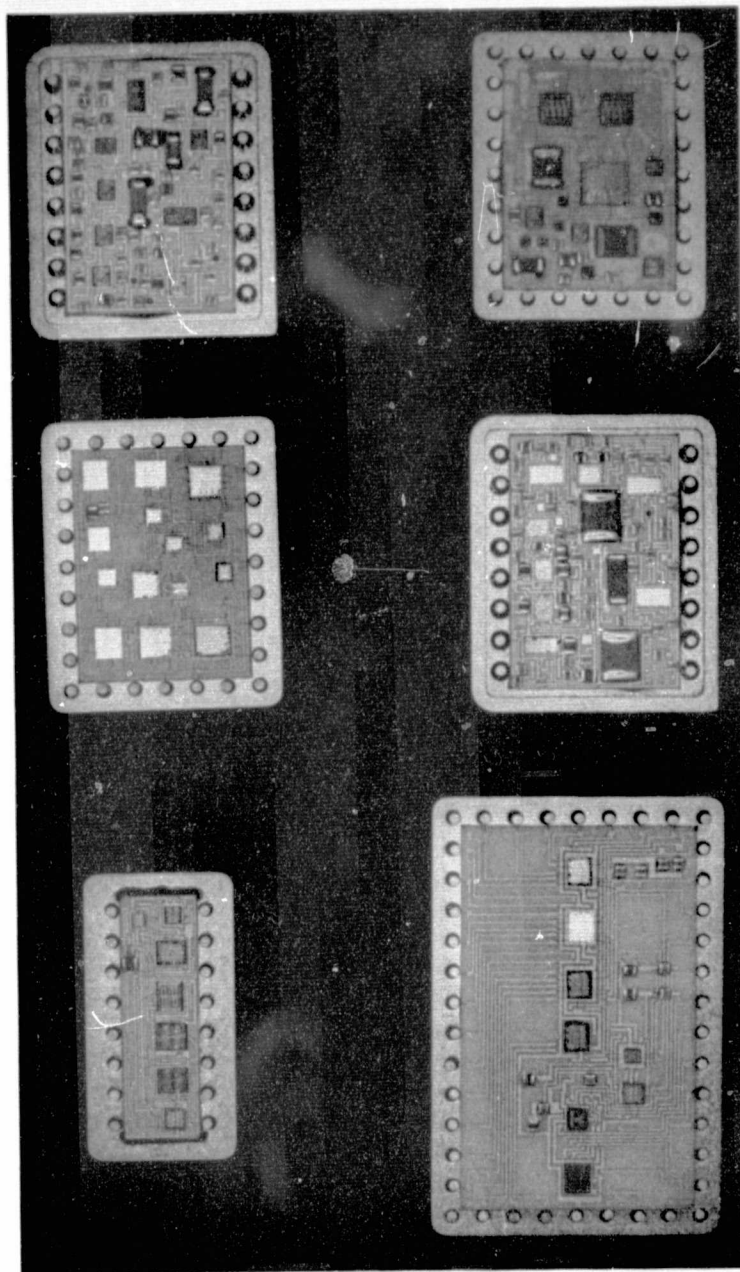
The assembled substrates were then attached to standard platform type headers and output connections made by wire bonding.

The packages were then sealed with non conductive epoxy except for a small vent hole in the top of the case.

The packages were then vacuum evacuated for 12 hours, backfilled with dry nitrogen and then the vent holes were sealed with non conductive epoxy.

Figure 6 is a photograph of the six circuits before they were sealed.

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VITAL SIGNS HYBRID DEVICES

FIGURE 6

V. TESTING

The acceptance tests for all digital circuitry was that it faithfully performs its prescribed function for all operational conditions.

The following are the acceptance test procedures for the ECG Amplifier and Impedance Pneumograph circuits.

1. ECG Acceptance Test Procedure

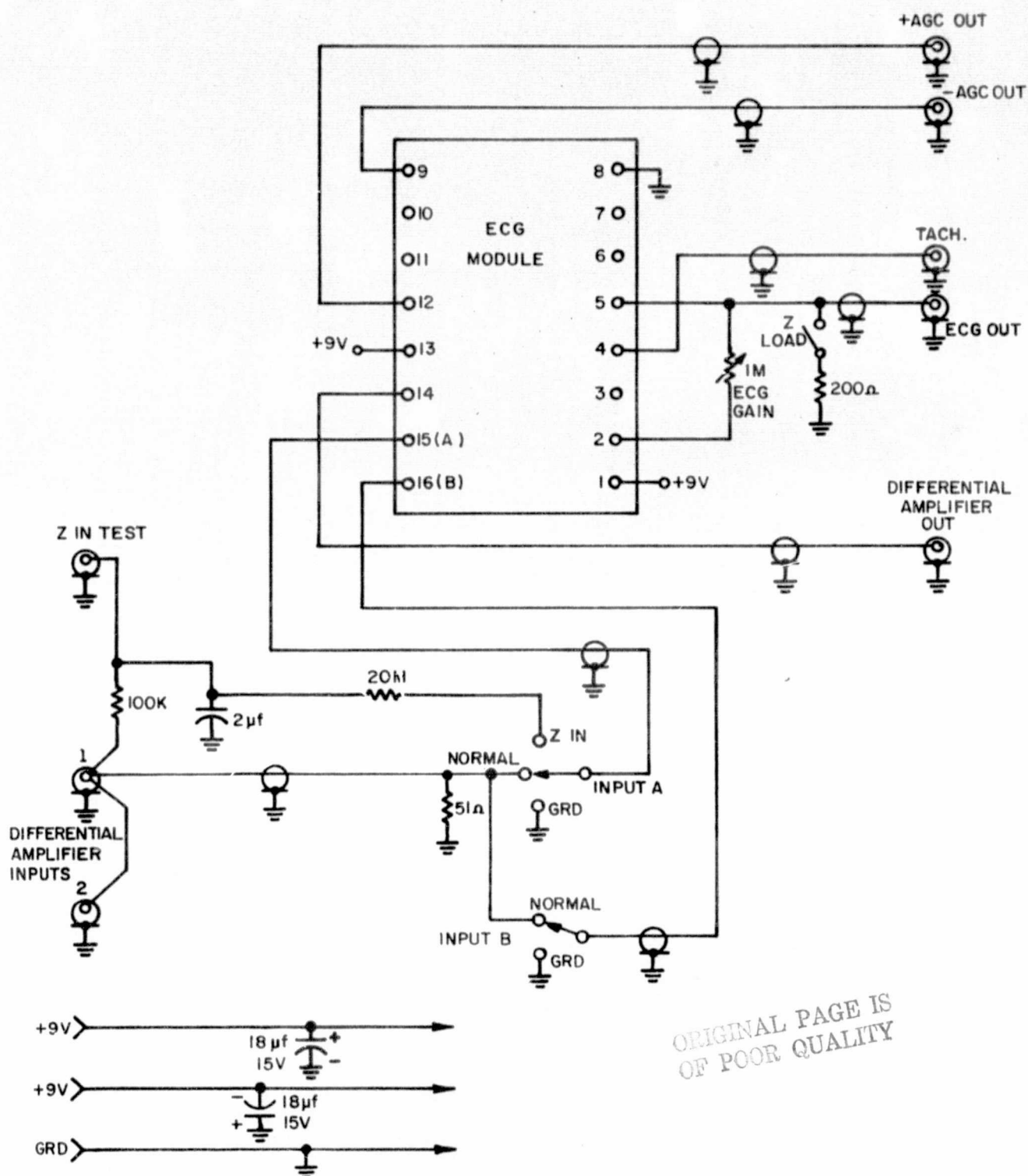
a. Input Amplifier Differential Gain Measurement

- (1) Connect a Hewlett-Packard Function Generator Model 3310A low output to a H.P. Model 355D attenuator. Connect the attenuator output to the "Diff. Amp. Input" of the ECG Acceptance Test Unit, Figure 7. Set the attenuator to 10 db.
- (2) Connect a Burr Brown Model 300 RMS voltmeter to the "Diff. Amp. Output" of the Test Unit.
- (3) Set the Test Unit "Input A" switch to "Normal", and Input B switch to "Gnd".
- (4) Set the Function Generator controls as follows:

Function switch	- sinewave
Frequency	- 60 Hz
Offset	- Zero
Level	- Adjust to read +10 db (2.44 volts rms) on voltmeter
- (5) Reconnect the RMS voltmeter to the "Diff. Amp. Input" using the second input connector.
- (6) The input should read very nearly -30 db (.0244 volts rms). Record the differential gain which must be 40 ± 1 db.

b. Input Amplifier Common Mode Gain Measurement

- (1) Maintain the Burr Brown RMS voltmeter connection to the "Diff. Amp. Input" of the Test Unit.
- (2) Set the Test Unit "Input B" switch to "Normal". Do not change "Input A" switch.
- (3) Change the Function Generator Output connector to High output.
- (4) Set the H.P. attenuator to 0 db.
- (5) Adjust the input level to read +10 db (2.44 volts RMS).



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ECG ACCEPTANCE TEST UNIT

FIGURE 7

- (6) Move the Burr Brown RMS voltmeter to the "Diff. Amp. Output" and record the amplifier common mode gain. Gain is thus $-[+10\text{db} - (-XX)] = -50\text{ db}$
The gain must be equal to or greater than -50 db .

c. Input Amplifier Output d.c. Offset

- (1) Reduce the Function Generator output to zero.
- (2) Replace the Burr Brown RMS voltmeter connected to the "Diff. Amp. Output" with a d.c. coupled oscilloscope.
- (3) Record the Differential Amplifier Output d.c. offset. It must be less than ± 1 volt at room temperature.

d. Input Impedance - Differential

- (1) Set the Test Unit "Input A" switch to the "Z_{in}" position, and "Input B" switch to "Gnd".
- (2) Connect a d.c. coupled oscilloscope to the Test Unit "Diff. Amp. Output". Set the oscilloscope sensitivity to 2 volts/division.
- (3) Set the Function Generator and associated attenuator controls as follows:

Function switch	- sinewave
Frequency	- 5 Hz
Offset	- as necessary
Level	- see step 4
Output source	- High output
Attenuator	- 20 db

- (4) By means of the Function Generator offset control, set the output d.c. voltage to zero as measured on the oscilloscope. Adjust the input level to provide 12 volts peak-to-peak at the output as measured on the oscilloscope.
- (5) Move the oscilloscope probe to connector "Z_{in} test" and record the peak-to-peak 5 Hz amplitude. It must be less than 180 mv.

e. ECG Amplifier Output d.c. Offset

- (1) Set the Test Unit "Input A" switch to "Gnd" and maintain "Input B" switch to "Gnd" position. Remove the Function Generator from the "Diff. Amp. Input."

- (2) Connect the d.c. coupled oscilloscope to the Test Unit "ECG Output" connector. Set the oscilloscope sensitivity at 100 millivolts/div.
- (3) Adjust the "ECG Gain" control for maximum gain (fully clockwise).
- (4) Record the ECG Amplifier Output d.c. offset. It must be less than ± 0.25 volts d.c. at room temperature.

f. ECG Amplifier Maximum Overall Gain

- (1) Set the Test Unit "Input A" switch to "Normal", and maintain "Input B" switch in "Gnd" position. Maintain the "ECG Gain" control at maximum.
- (2) Maintain the d.c. coupled oscilloscope connection to "ECG Output". Set oscilloscope sensitivity to 2 volts/division.
- (3) Connect the Function Generator to the "Diff. Amp. Input" and set control as follows:

Function switch	- sinewave
Frequency	- 5 Hz
Offset	- Zero
Level	- See step 4
Output source	- Low output
Attenuator	- 40 db
- (4) Adjust the input level control to provide 10 volts peak-to-peak at the output as measured on the oscilloscope. Note the sinewave fidelity and record.
- (5) Move the oscilloscope probe to the second "Diff. Amp. Input" and record the peak-to-peak 5 Hz amplitude. It must be less than 2.2 millivolts.

g. ECG Minimum Overall Gain

- (1) Maintain the Test Unit "Input A" switch at "Normal", and "Input B" switch in "Gnd" position. Adjust the "ECG Gain" control to minimum gain (fully CCW).
- (2) Connect the d.c. coupled oscilloscope to "ECG Output." Set the oscilloscope sensitivity to 2 volts/division.
- (3) Maintain the Function Generator connection to the "Diff. Amp. Input" and set controls as follows:

Function switch	- sinewave
Frequency	- 5 Hz
Offset	- Zero
Level	- See step 4
Output source	- low output
Attenuator	- 20 db

- (4) Adjust the Function Generator level control to provide 10 volts peak-to-peak at the output as measured by the oscilloscope.
- (5) Move the oscilloscope probe to the second "Diff. Amp. Input" and record the peak-to-peak 5 Hz amplitude. It must be greater than 16 millivolts. Also compute and record the gain when the control is set to minimum (typically 625).

h. Output Noise Referred to Input

- (1) Disconnect the Function Generator from the "Diff. Amp. Input" and set the "Input A" and "Input B" switches to "Gnd" position.
- (2) Connect the oscilloscope to the "ECG Output", and measure the peak-to-peak output noise. Calculate the noise referred to the input by using the amplifier gain computed in Part g.

$$\text{Example: } \frac{\text{Noise at output}}{\text{Gain}} = \frac{4 \text{ mV}}{625} = 6.4 \text{ microvolts}$$

Record the calculated value which must be less than 10 microvolts peak-to-peak.

i. ECG Amplifier Frequency Response

- (1) Set the Test Unit "Input A" switch to "Normal", and "Input B" switch to "Gnd."
- (2) Maintain the connection of the d.c. coupled oscilloscope to the "ECG Output". Set the oscilloscope sensitivity to 1 volt/division.
- (3) Reconnect the Function Generator to the "Diff. Amp. Input" and set controls as follows:

Function switch	- sinewave
Frequency	- 2 Hz
Offset	- Zero
Level	- See step 4
Output source	- low output
Attenuator	- 20 db

- (4) Adjust the Function Generator level control to provide 5 volts peak-to-peak at the output as measured by the oscilloscope.
- (5) Slowly change the frequency from 2 Hz up to 35 Hz and down to 0.14 Hz. Note and record the maximum amplitude spread over this frequency span. It must not exceed 1 db.

Note: If the Function Generator has not been recently checked for amplitude stability versus frequency, it should be verified before this acceptance test is performed.

- (6) Measure and record the output amplitude with respect to 2 Hz at 0.05 Hz and 100 Hz. It must be $-3 \text{ db} \pm 1 \text{ db}$.

j. ECG Amplifier Output Impedance

- (1) Set the Test Unit "Input A" switch to "Normal", and "Input B" switch to "Gnd".
- (2) Connect the Function Generator to the "Diff. Amp. Output", but first set the controls as follows:

Function switch	- sinewave
Frequency	- 10 Hz
Offset	- Zero
Level	- Minimum
Output source	- low output
Attenuator	- 40 db
- (3) Verify that the "ECG Gain" control is at minimum (fully CCW).
- (4) Connect the Burr Brown RMS voltmeter to the "ECG Output". Set the voltmeter sensitivity to 30 mv rms.
- (5) Adjust the Function Generator level control to provide 25 millivolts RMS as monitored by the RMS voltmeter.
- (6) Check the output waveform with the oscilloscope to guarantee the sinewave is not clipped when the Z_o switch is closed. If clipping occurs, the output level must be reduced until fidelity is restored.
- (7) Read and record the RMS voltage before and after Z_o switch is closed. The 200 ohm load must not reduce the output to less than half the original value.

k. AGC Output Amplitude

- (1) Set the Test Unit "Input A" switch to "Normal", and "Input B" switch to "Gnd".

- (2) Connect the Function Generator to the "Diff. Amp. Input", and set the controls as follows:

Function switch	- positive pulse
Frequency	- 1 Hz
Offset	- Zero
Output source	- low output
Level	- Maximum
Attenuator	- 54 db

- (3) Connect the oscilloscope to "+AGC Out". Read and record the peak pulse amplitude. It must be 2 ± 0.1 volts.
- (4) Connect the oscilloscope to "-AGC Output". Read and record the peak pulse amplitude. Again it must be 2 ± 0.1 volts.
- (5) Set the "Input A" switch to "Gnd", and "Input B" switch to "Normal".
- (6) Repeat steps 3 and 4.

1. Cardiometer Signal Conditioner Output

- (1) Maintain the "Input A" switch to "Gnd" and "Input B" switch to "Normal".
- (2) Connect the Function Generator to the "Diff. Amp. Input", and set the controls as follows:

Function switch	- positive pulse
Frequency	- 1 Hz
Offset	- Zero
Output source	- low output
Level	- Maximum
Attenuator	- 54 db

- (3) Connect the oscilloscope to "Tach Out". Read and record the pulse output. It must be > 7.5 volts and 100 ± 15 ms duration.

2. Impedance Pneumograph Acceptance Test Procedure

a. Excitation Frequency, Waveshape and Amplitude

- (1) Connect an oscilloscope to "Terminal A" of the Test Unit, Figure 8. The oscilloscope probe input capacitance must not exceed 10 pf.
- (2) Switches "#1" and "#2" located on the Test Unit must be open.
- (3) The waveform present at "Terminal A" must be triangular shaped and approximately 10 volts peak-to-peak. The

frequency must be 50 ± 5 kHz. Record amplitude and frequency.

- (4) Repeat above steps 1 through 3 with the oscilloscope probe connected to "Terminal B."

b. Excitation Current

- (1) Close Switch "#1" (Switch #2 remains open) and maintain the oscilloscope connection to Terminal "B".
- (2) The waveform must be approximately square shaped, and less than 0.25 volts zero to peak both positive and negative half cycle. Record the peak amplitudes.
- (3) Repeat steps 1 and 2 above with the oscilloscope probe connected to "Terminal A".

c. Differential Amplifier and Rectifier

- (1) Connect a d.c. coupled oscilloscope to the "Rectified 50 kHz Out" connector of the Test Unit.
- (2) Close both "Switches #1 and #2."
- (3) Read and record the d.c. level. It must not exceed +0.3 volts.
- (4) Open "Switch #2" and read and record the d.c. level at the "Rectified 50 kHz Out". This reading minus the reading obtained in step 3 must not be less than 2.0 volts.

d. Pneumograph Amplifier Gain and Frequency Response

- (1) Connect the d.c. coupled oscilloscope to the "Impedance Pneumograph Out" connector of the Test Unit.
- (2) Close "switch #2". Read and record the d.c. offset at the Impedance Pneumograph Output. The offset must not exceed ± 2 volts.
- (3) Connect a Hewlett-Packard Function Generator Model 2110A low output to a H.P. Model 355D attenuator. Connect the attenuator output to the "Rectified 50 kHz Out" of the Test Unit.
- (4) Set the Function Generator and associated attenuator controls as follows:

Function switch	- sinewave
Frequency	- 1 Hz
Offset	- Zero
Level	- minimum
Output source	- low output
Attenuator	- -20 db

- (5) Adjust the input level control to provide 6 volts peak-to-peak at the output as measured on the oscilloscope.
- (6) Move the oscilloscope probe to the "Rectified 50 kHz Out" number 2. Read and record the peak-to-peak 1 Hz amplitude. The gain must be $200 \pm 10\%$.
- (7) Move the oscilloscope probe to the "Impedance Pneumograph Out" and verify that the 1 Hz level is 6 volts peak-to-peak.
- (8) Raise the Function Generator Frequency to provide 4.25 volts Output peak-to-peak. Read and record the frequency.

Note: A frequency counter may be required. The frequency must be 10 ± 1 Hz.

e. One Hertz Low Pass Filter and d.c. Restorer

- (1) Maintain the Function Generator and attenuator connected to the "Rectified 50 kHz Out" of the Test Unit.
- (2) Set the Function Generator and associated attenuator controls as follows:

Function switch	- sinewave
Frequency	- 0.3 Hz
Offset	- Zero
Level	- minimum
Output Source	- Low output
Attenuator	- - 30 db
- (3) Connect the d.c. coupled oscilloscope to the "Filtered and d.c. restored Z-P out" of the Test Unit.
- (4) Adjust the input level control to provide 0.6 volts peak-to-peak at the output as measured by the oscilloscope. There must be no discernible limiting of either peak.
- (5) Move the oscilloscope probe to the "Impedance Pneumograph Out" connector. Read and record the peak-to-peak 0.3 Hz sinewave. The gain must be $0.9 \pm 10\%$.
- (6) Move the oscilloscope probe to the "Filtered and d.c. restored Z-P Out." Raise the Function Generator Frequency to provide 0.425 volts output peak-to-peak as measured by the oscilloscope. Read and record the frequency. It must be 1 ± 0.1 Hz.

- (7) Lower the Function Generator Frequency to provide 0.425 volts output peak-to-peak as measured by the oscilloscope. Read and record the frequency. It must be 0.09 ± 0.01 Hz.
- (8) Raise the Function Generator frequency again to 0.3 Hz. Increase the input level control until the oscilloscope shows definite limiting of both peaks. Read and record the zero to peak value for both positive and negative peaks. The positive peak must be 0.7 ± 0.1 volts and the negative peak 0.6 ± 0.1 volt.

f. Pulse Out to Respiration Rate Counter

- (1) Maintain all Function Generator and attenuator controls as used in Part e-8 above. Move the oscilloscope probe to the "Pulse Out to Respiration Rate Counter" connector. Read and record the pulse high state and low state voltage. They must be as follows:

$$V_H = 7.5 \text{ volts min.}$$

$$V_L = 0.1 \pm 0.1 \text{ volts}$$

VI. BREADBOARD VITAL SIGNS MONITOR

During the course of the contract, it was amended to replace a test system to be furnished by NASA, JSC, with a test unit to be developed by the University for functional evaluation of the devices specified in the contract. The original test set-up consisted of several sockets on a set of printed circuit boards interconnected by flat cable. When this set up was reviewed, it became obvious that the entire package could be integrated into a printed circuit board, and a digital display unit could be added, along with a battery and case, to provide a reliable, small, hand-carried physiological monitoring unit that would be a major contribution to the increasingly useful array of electronic equipment available for emergency use in remote areas or tight spaces. The ensuing development is named herein, the Vital Signs Monitor, the subject of this disclosure of new technology. The schematic layout of the basic pc board with hybrid devices in place, which constitutes the Vital Signs Monitor, is illustrated in drawing EB-13542.

The development effort to produce the Vital Signs Monitor evolved from a design review of the existing measurement devices which were scheduled to be hybridized, namely: 1) the existing system power requirements were considered to be too high for effective hybridizing, 2) the particular design philosophy used for the subsystems or devices were not conducive to hybridizing, i.e., the required interconnect lines placed a burden on the "pin-limited" characteristics of hybrid packages, the impedance levels of the circuitry were too low to allow the use of small capacitors as is necessary in good hybridization technique, 3) it was desirable to reduce the number of required calibration adjustments that were present in the existing system, and 4) it was desirable to provide more flexibility in configuring the subsystems into overall systems than was possible in the existing measurement system.

The Vital Signs Monitor is a miniaturized measurement system organized into a complete, integrated package consisting of six hybrid circuits, display, a motherboard, batteries and case, with appropriate transducers for interfacing to the human body. The system is capable of measuring and displaying body temperature, heart rate and breath rate. In addition, an ECG (electrocardiogram) and respiration signals are available as an output and provisions exist for displaying blood pressure data that are processed in external circuitry.

The Vital Signs Monitor has been developed to a prototype state, and a demonstration unit has been constructed. The final packaging could be much smaller than the demonstration unit.

The Vital Signs Monitor is a portable, battery operated measuring unit which processes the signals generated by a thermistor (for measuring body temperature) and chest electrodes (for measuring heart rate and breath rate), then displays them on a multi-display. The display circuit was developed in a way that allows various combinations of vital signs functions into any system configuration that is desirable.

The temperature is determined by an electronic thermometer circuit which has a range from 80 to 110°F with an accuracy of at least $\pm 1\%$ of the absolute value and is displayed to the nearest one-tenth degree. The heart rate is determined by an ECG Amplifier and Cardiometer Signal Conditioner circuit, and a Heart Rate/Breath Rate Processor circuit which has a range from

40 to 199 beats per minute with an accuracy of at least $\pm 2\%$ plus one beat of full range. The heart rate can be computed on a beat-to-beat basis or upon five consecutive periods between heart beats and is displayed to the nearest beat. The breath rate is determined by an Impedance Pneumograph and Respiration Rate Signal Conditioner device and a Heart Rate/Breath Rate Processor device which has a range from 6 to 24 breaths per minute with an accuracy of at least $\pm 2\%$ plus one breath of full range. The Heart Rate/Breath Rate Processor circuit was designed in such a way that could be used for either heart rate or breath rate.

The data output circuits of the vital signs function processors and the display circuits, were designed in such a manner as to provide great flexibility in the display of data and allows several different modes to be used. The various types of display systems that can be used are as follows:

- 1) 16 digit liquid crystal display (LCD)
- 2) 4 digit liquid crystal display (with function selection)
- 3) 16 digit light emitting diode (LED) display, and
- 4) 4 digit light emitting diode display (with function selection).

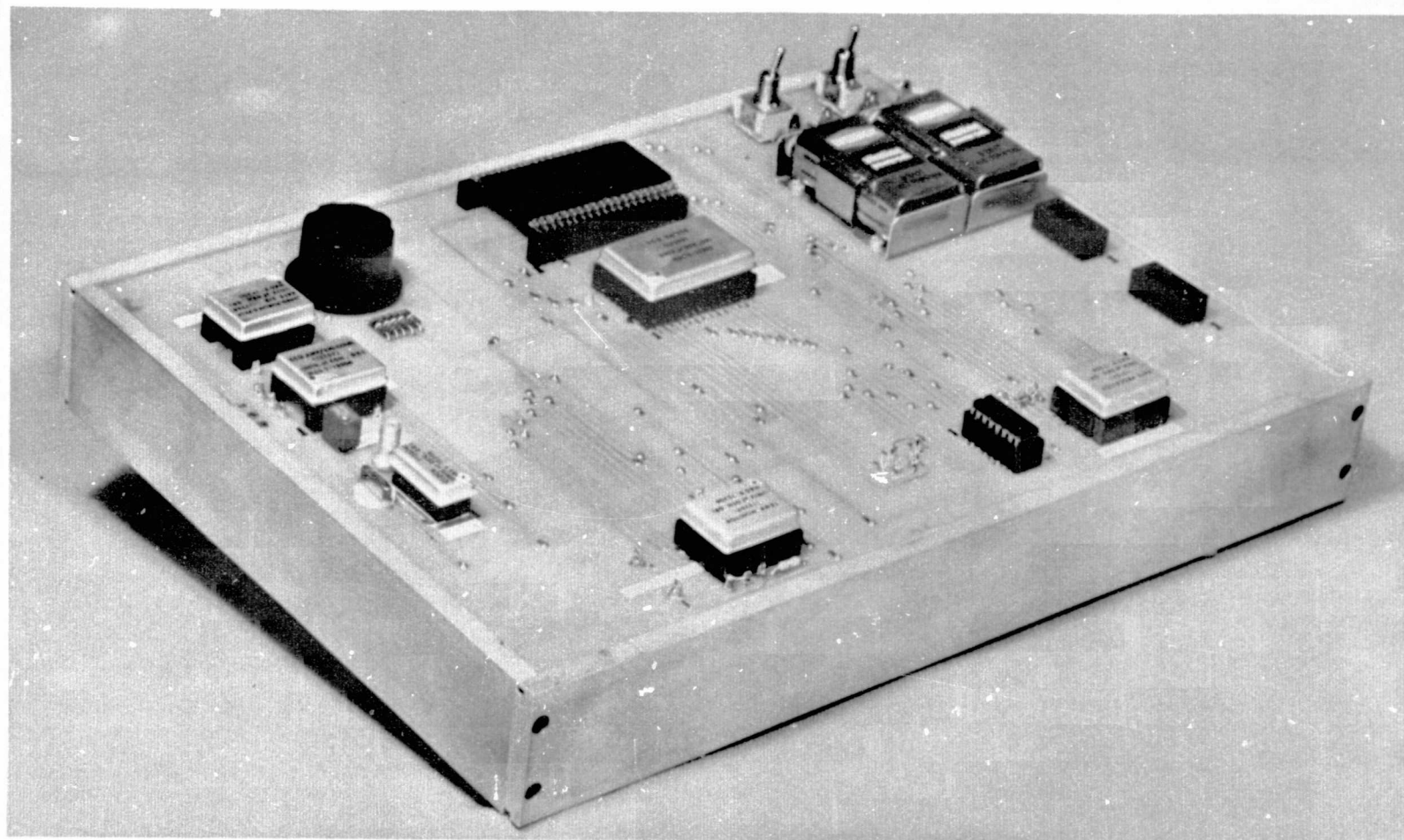
In addition, the types of LED displays that can be used to display the vital signs data in the last two cases listed above are:

- 1) Multiple digit LED displays with I/O lines for seven-segment selection for each digit and multiplexing between digits,
- 2) Combinations of separate seven-segment LED digit displays,
- 3) Combinations of separate LED displays which accept BCD data input to a latch register and having BCD-to-seven segment decoder, and
- 4) Multiple digit LED displays which require one set of BCD data input lines and separate digit latch commands to latch registers having BCD-to-seven segment decoders.

It is also noted that the data output circuits being used in the function processors exhibit the inherent flexibility that allows interfacing this data to parallel-to-serial converters for transmission of data long distances over a single twisted-pair line, and also will allow simple interfacing to microprocessing or minicomputing systems should such requirements ever arise at a later date.

Figure 9 is a photograph of the completed breadboard vital signs system.

Figure 10 is an artists conception of a small hand held vital signs monitor that could be produced for the system as presented here.

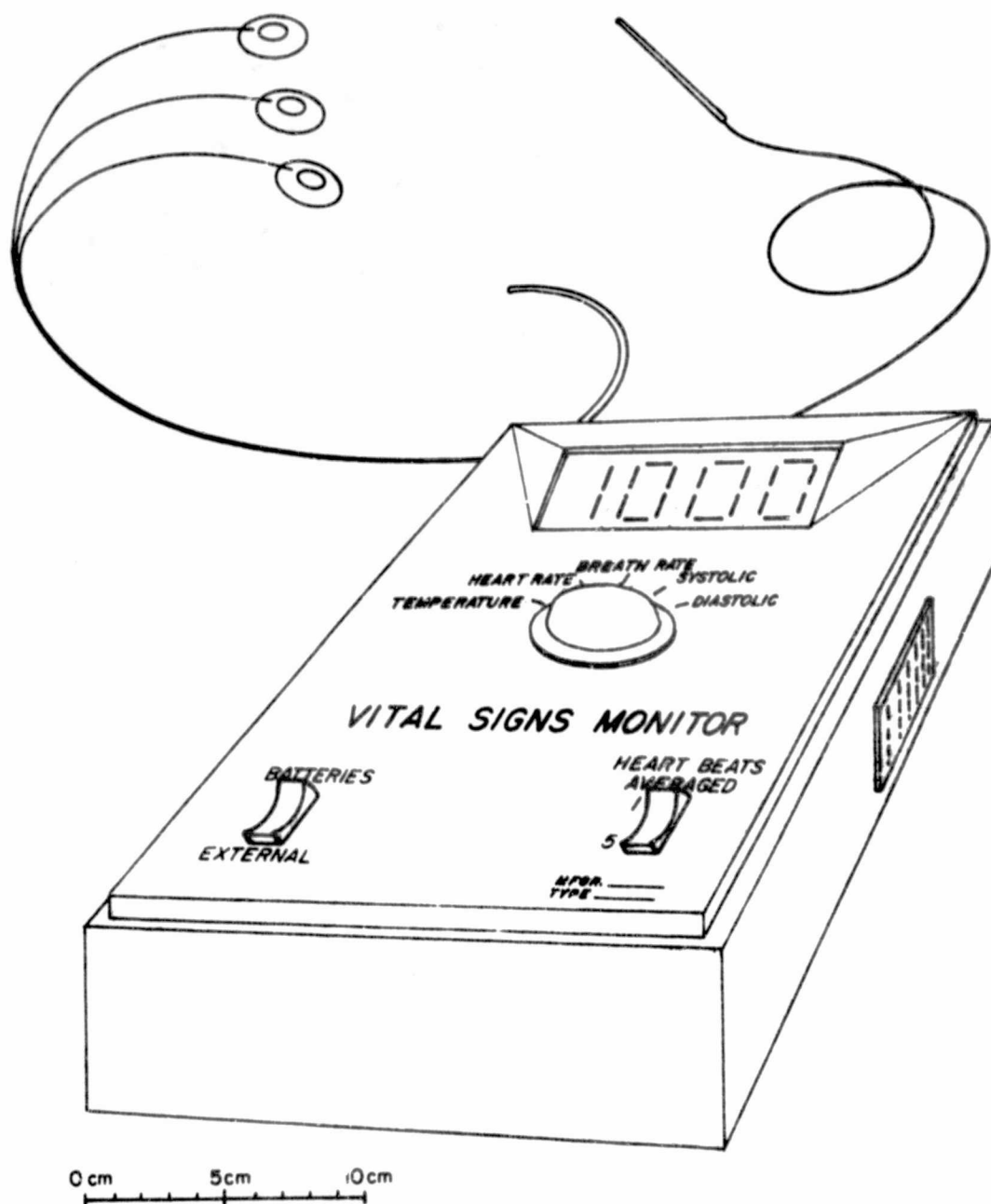


PROTOTYPE OF

Vital Signs Monitor, developed by the Electronics Division of the Denver Research Institute, a department of the University of Denver, features liquid crystal digital display of the heart rate, breath rate, blood pressure and temperature. The instrument was developed for NASA, Johnson Space Center, Houston.

Figure 9

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ARTISTS CONCEPT OF VITAL SIGNS MONITOR

FIGURE 10

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VII. SHIPPING

All hybrids were shipped in conductive foam to protect any CMOS devices. This procedure was followed even for those circuits in which no CMOS devices were used since almost all circuits did contain CMOS devices.

The caution statement given in Appendix D was included in each box of hybrid circuits.

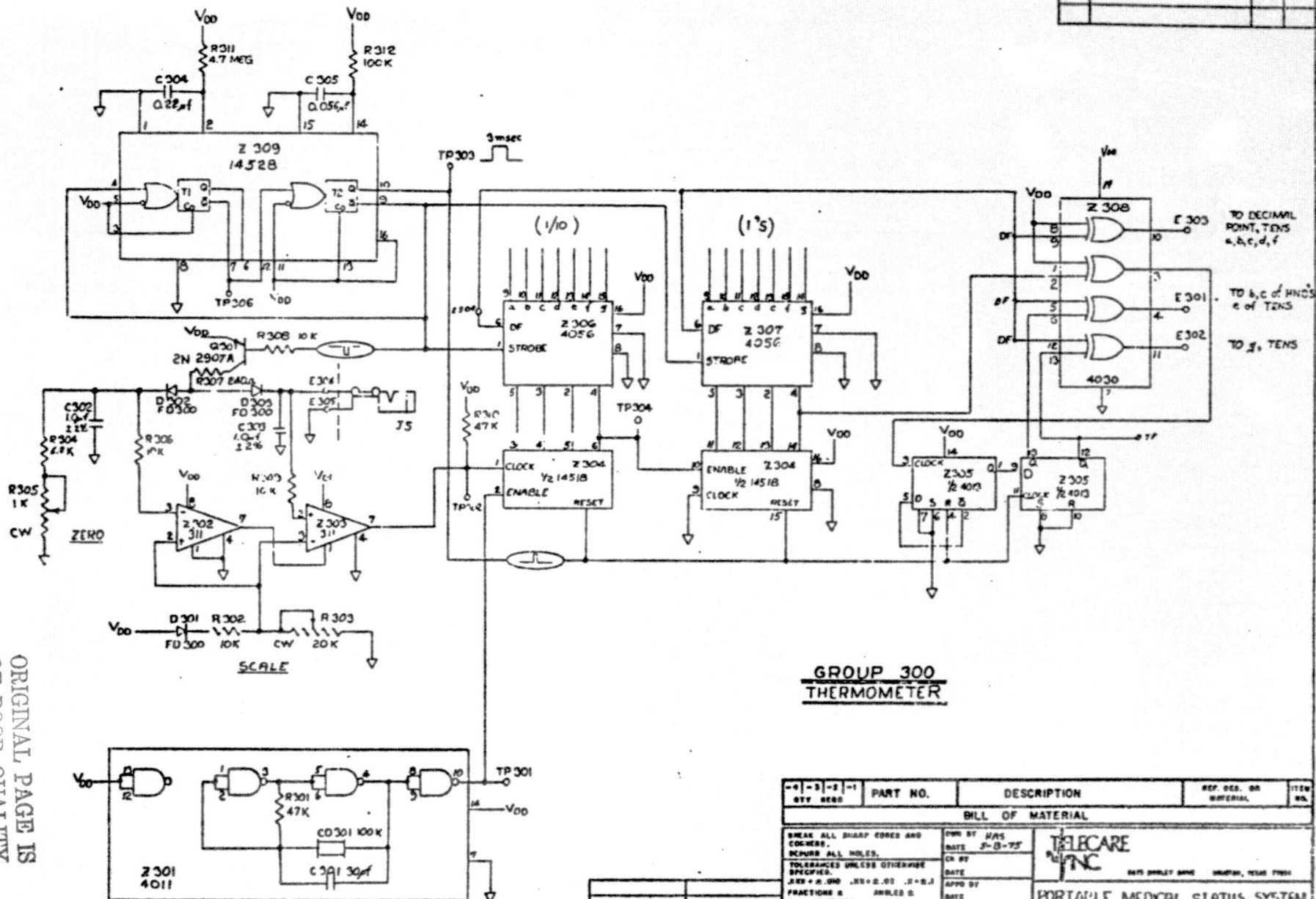
The breadboard circuit was packed and shipped separately.

APPENDICES

APPENDIX A

Proposed NASA Circuit Diagram

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GROUP 300 THERMOMETER

REV	REV	REV	REV	PART NO.	DESCRIPTION	REF. DES. OR MATERIAL	ITEM NO.
1	1	1	1		BILL OF MATERIAL		
BREAK ALL DIMENSIONS AND COORDINATES.				OWN BY H/S			
SECURE ALL HOLES.				DATE 3-13-75			
TOLERANCES UNLESS OTHERWISE SPECIFIED.				CR BY			
.XES + .X.UND .XES + .X.UND .X + .X.UND				DATE			
FRACTIONS & ANGLES & SURFACE FINISH				APPRO BY			
MATERIAL				DATE			
FINISH				DATE			
USED ON				NEXT ASSY			
APPLICATION				FINISH			
				TELECAR INC			
				PORTABLE MEDICAL STATUS SYSTEM GROUP 300			
				COST NEXT			
				SCALE			
				UNIT WT.			
				SH OF			
				PART NO. 501355			
				REV.			

ANALOG INPUT FROM ECG

R403 39 K

C402 0.1

R404 47 K

Z402 741

R405 910 Ω

R409 1 K

R410 10 K

R411 100 K

C404 0.022

R412 10 K

R413 100 K

R414 10 K

R415 10 K

R416 10 K

R417 10 K

R418 10 K

R419 10 K

R420 10 K

R421 10 K

R422 10 K

R423 10 K

R424 10 K

R425 10 K

R426 10 K

Z403 741

Z404 741

Z405 741

TP401

TP402

TP403

TP404

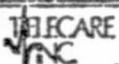
ANALOG OUTPUT

AGC ADJUST

T-F TO HEART RATE

GROUP 400

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-C -3 -2 -1 RTY RECD	PART NO.	DESCRIPTION	REF DES OR MATERIAL	ITEM NO.
BILL OF MATERIAL				
BREAK ALL SHARP EDGES AND CORNERS. REMOVE ALL HOLES. TOLERANCES UNLESS OTHERWISE SPECIFIED. JAX = N.O.D. UNLESS OF .0001 FRACTIONS IN ANGLES & SURFACE FINISH RMS MATERIAL	DWN BY #A5 DATE 8-16-75 CR BY DATE APPD BY DATE REC. ENG. DATE	 2070 WATLEY DRIVE HOUSTON, TEXAS 77060 PORTABLE MEDICAL STATUS SYSTEM GRALIP 400		
PART NO. 183273	CODE TRAY C	SIZE 1	PART NO. 501356	REC.
UNIT WT.	SCALE	IN	OF	

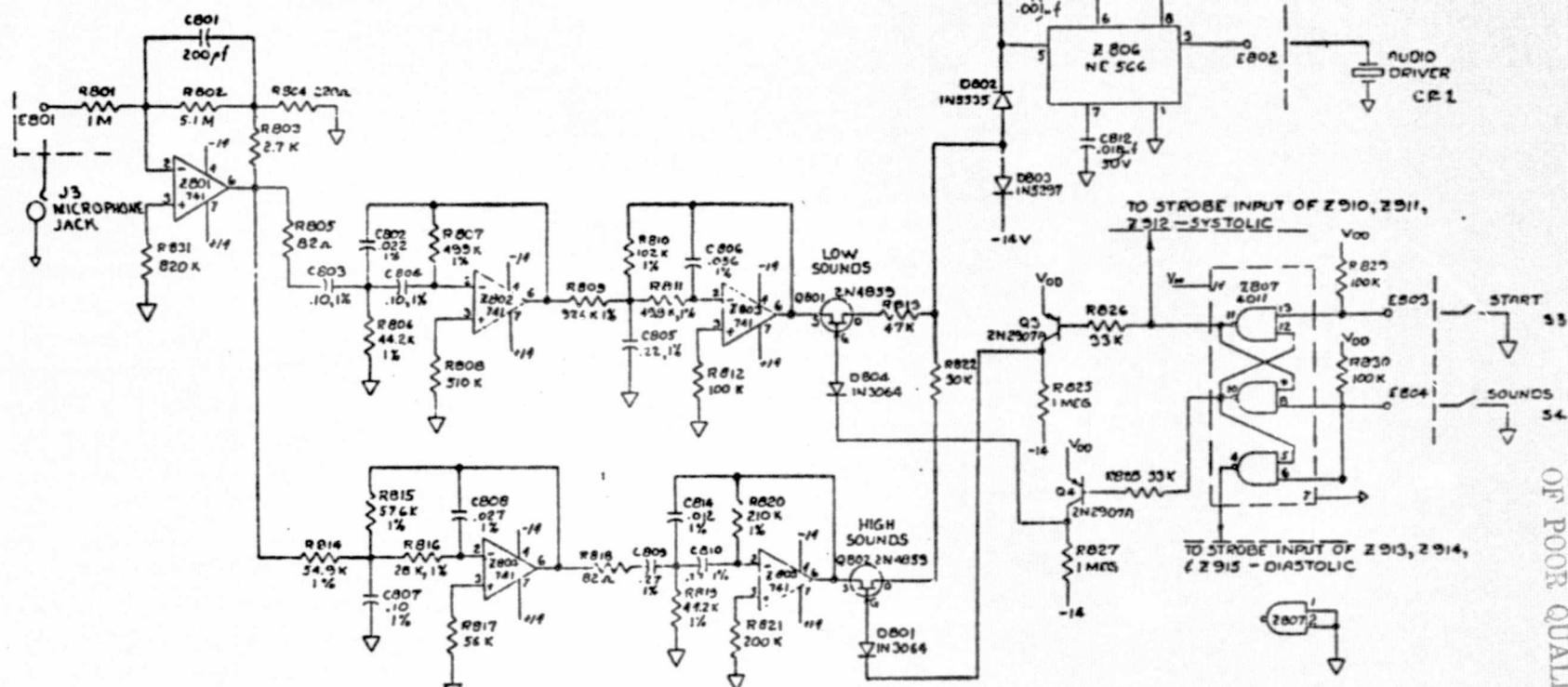
**GROUP 600
RESPIRATION RATE**

REV	DATE	BY	CHK	APP	DESCRIPTION
1	10-1-68	WTF	WTF	WTF	GROUP 600 RESPIRATION RATE

GROUP 600
RESPIRATION RATE

USED ON	NEXT AGENT
APPLICATION	

-6 -3 -1 STY SZ00	PART NO.	DESCRIPTION	REF. DES. OR MATERIAL	ITE NO.
BILL OF MATERIAL				
DRAW ALL SHARP EDGES AND CORNERS. DEBURR ALL HOLES. FINISHES UNLESS OTHERWISE NOTED. X.X = .X INCH X.Y = .Y DECIMAL X.Y Z = .Z THOUSTHS Z MILLIS Z SURFACE FINISH Z DIA		DATE BY MTC DATE BY J.S.T. DATE APPROV BY DATE L.C. ENG. DATE APPROV. EAC DATE	VIBRACASE PORTABLE MEDICAL STATUS SYSTEM GROUP 800	
MATERIAL		QTY REQD	UNIT	ITEM NO.
70000		1	EACH	501358
		DATE REC	DRAWN BY	BY S H P.



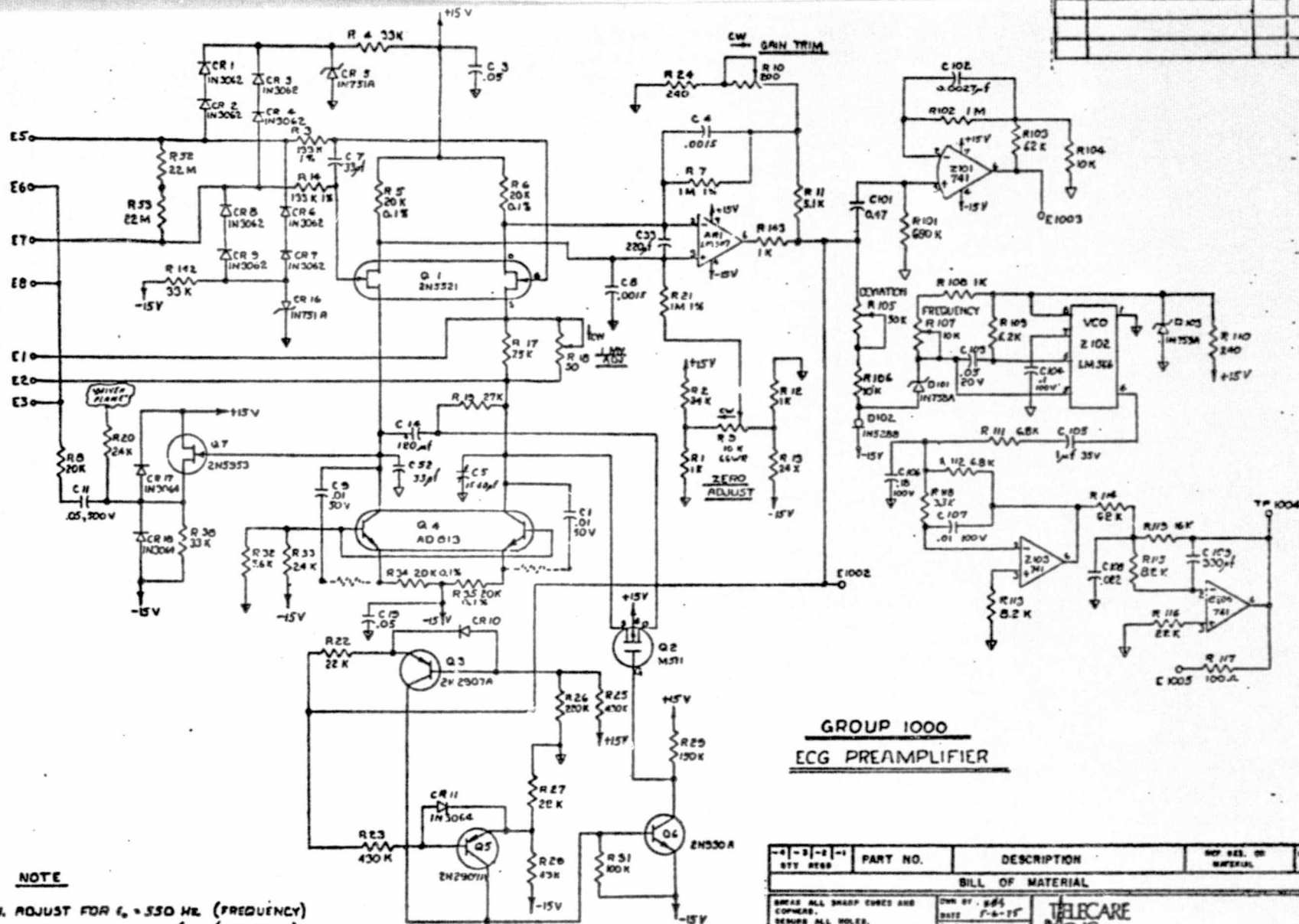
GROUP 800
SOUNDS PROCESSOR

USER ON	NEXT ASSY
APPLICATION	

QTY	REQD	PART NO.	DESCRIPTION	REF. DES. OR MATERIAL	ITEM NO.
BILL OF MATERIAL					
BREAK ALL SHARP CORNERS AND CHAMFER ALL HOLES. TOLERANCES UNLESS OTHERWISE SPECIFIED. XXX ± 0.015 .XX ± 0.005 .X ± 0.1 FRACTIONS IN .XXXLES 0 SURFACE FINISH RND MATERIAL			DWN BY JWS DATE 5-15-75 CK BY DATE APP'D BY DATE MFG. ENG. DATE PRIN. ENL. DATE 10-3-75		
FINISH			TELECARE INC. 5175 HWY 101, SUITE 100, HOUSTON, TEXAS 77060 PORTABLE MEDICAL STATUS SYSTEM GROUP 800		
UNIT WT.			SCALE ~ 1 of 1		

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NOTE

1. ADJUST FOR $f_c = 550$ HZ (FREQUENCY)
2. ADJUST FOR 75 HZ/mv (DEVIATION)

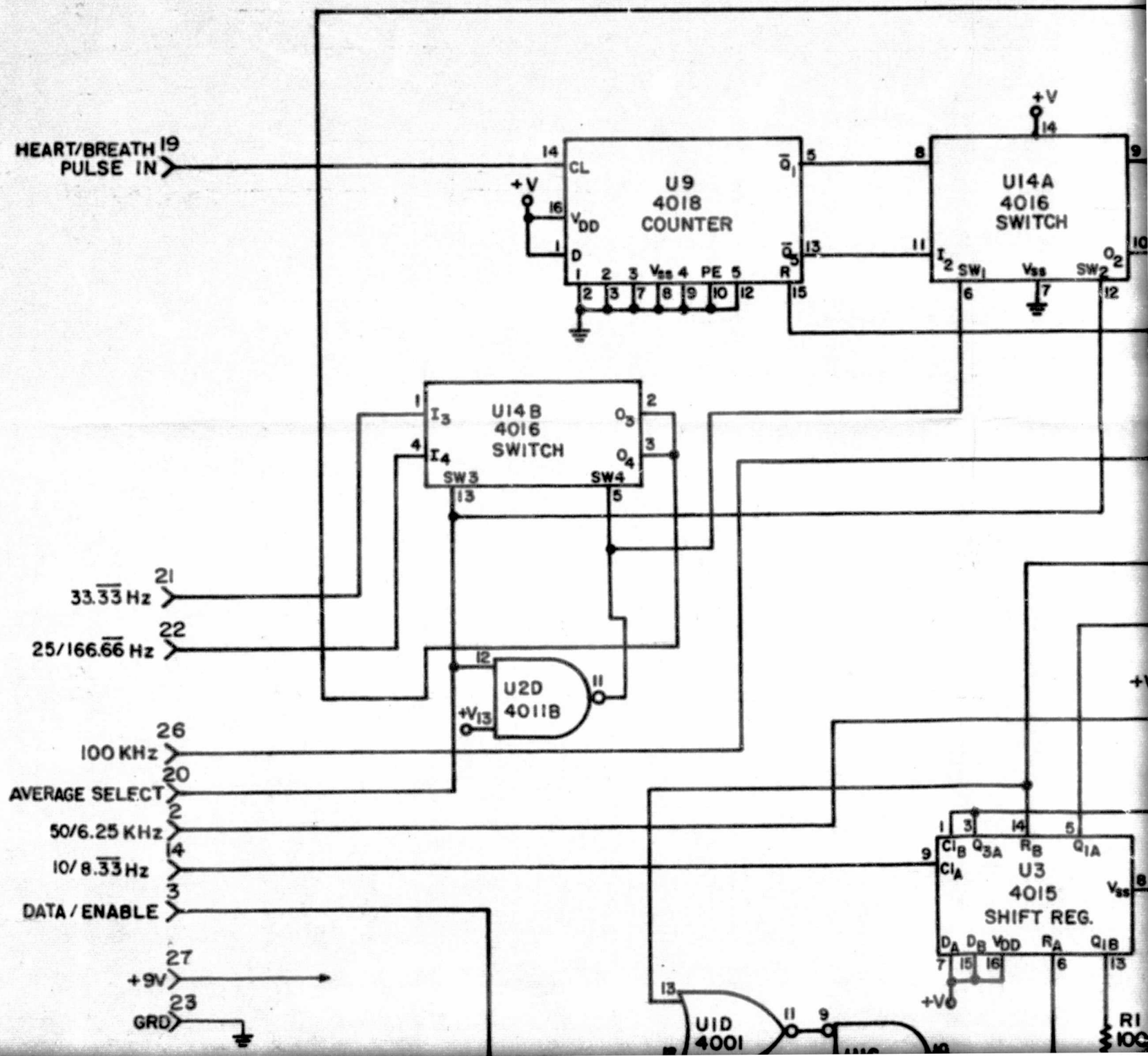
GROUP 1000
ECG PREAMPLIFIER

-4-3-2-1 STY RESS	PART NO.	DESCRIPTION	REF. RES. ON MATERIAL	REF. RES. ON
BILL OF MATERIAL				
BREAK ALL SHARP EDGES AND CORNERS. REMOVE ALL HOLES. DO NOT REWORK UNLESS OTHERWISE SPECIFIED. XXX = R.O.D. XX = R.O. X = S.I. FRACTIONS & ANGLES & SURFACE FINISH SHS	OWN BY <i>gag</i> DATE <i>5-6-75</i> CH BY DATE APPRO BY DATE MFG. ENG. DATE PRG. ENG. DATE <i>10-3-75</i>	TELECARE INC. 6150 WOODLEY DRIVE HOUSTON, TEXAS 77055	PORTABLE MEDICAL STATUS SYSTEM GROUP 1000	
MATERIAL	CODE NAME	SIZE	QTY NO.	UNIT
FOUR		C	501362	
	UNIT WT.	SCALE	IN	OUT

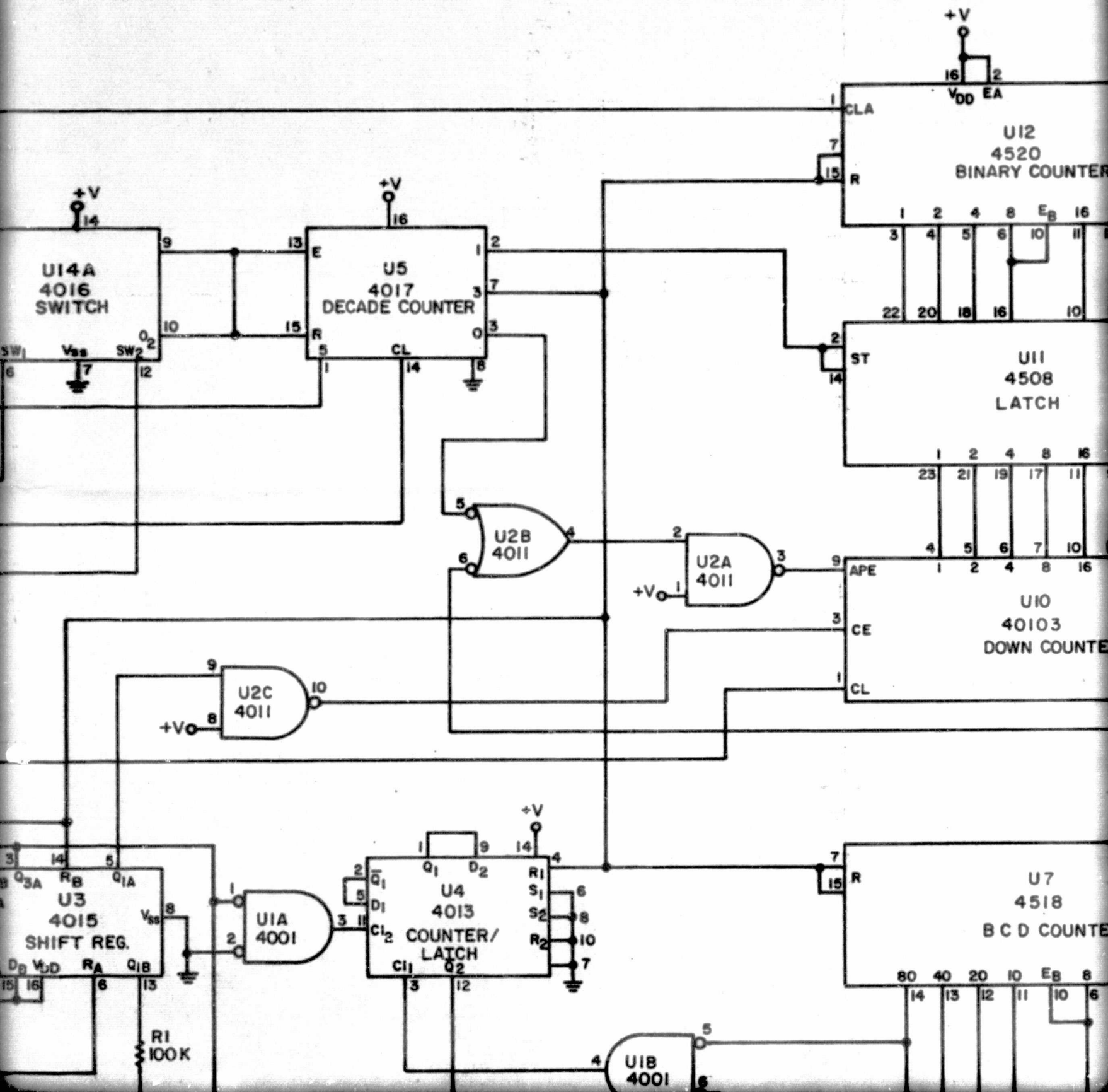
APPENDIX B

Schematic Diagrams

FOLDOUT FRAME



FOLDOUT FRAME 2



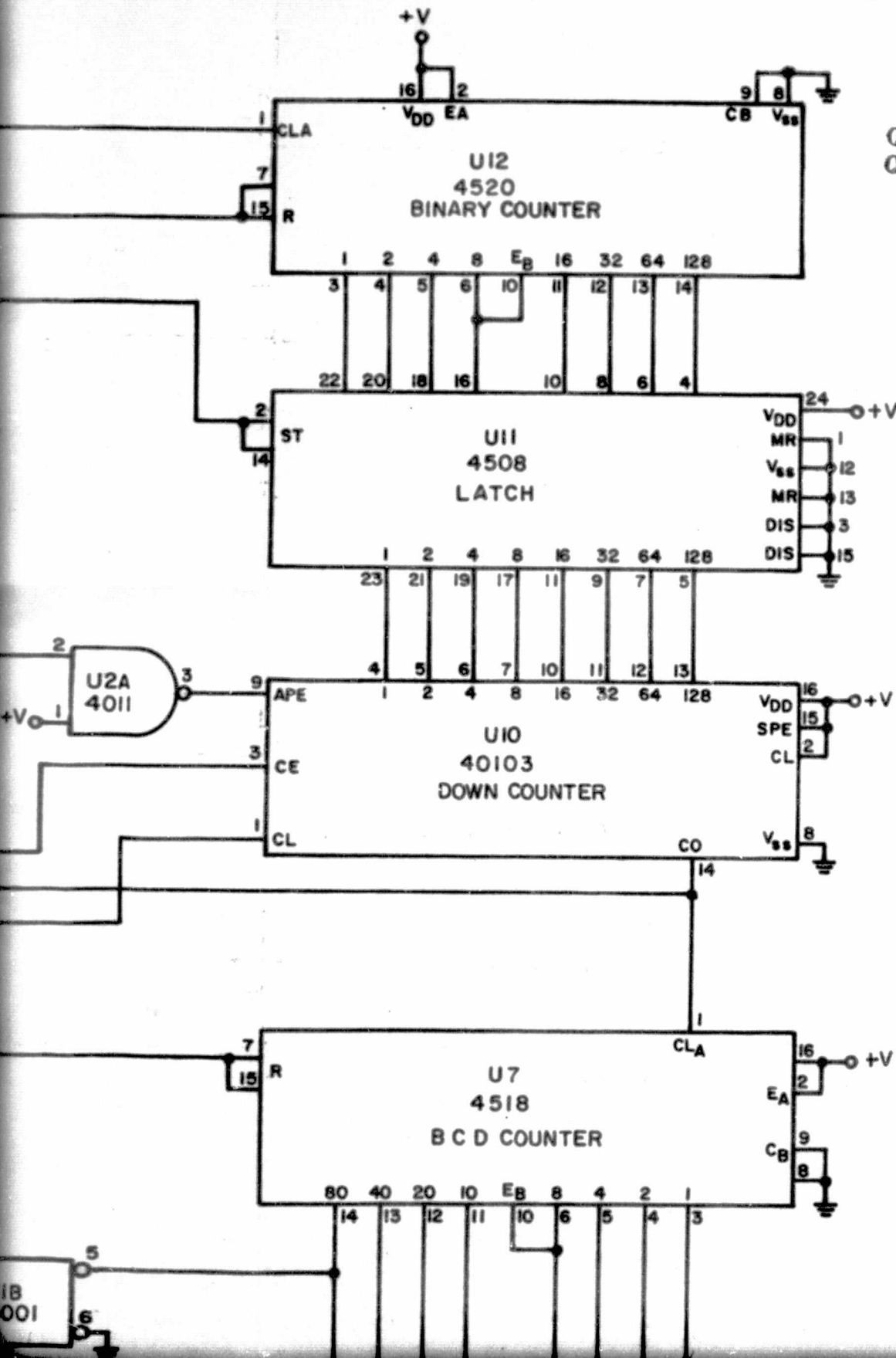
G

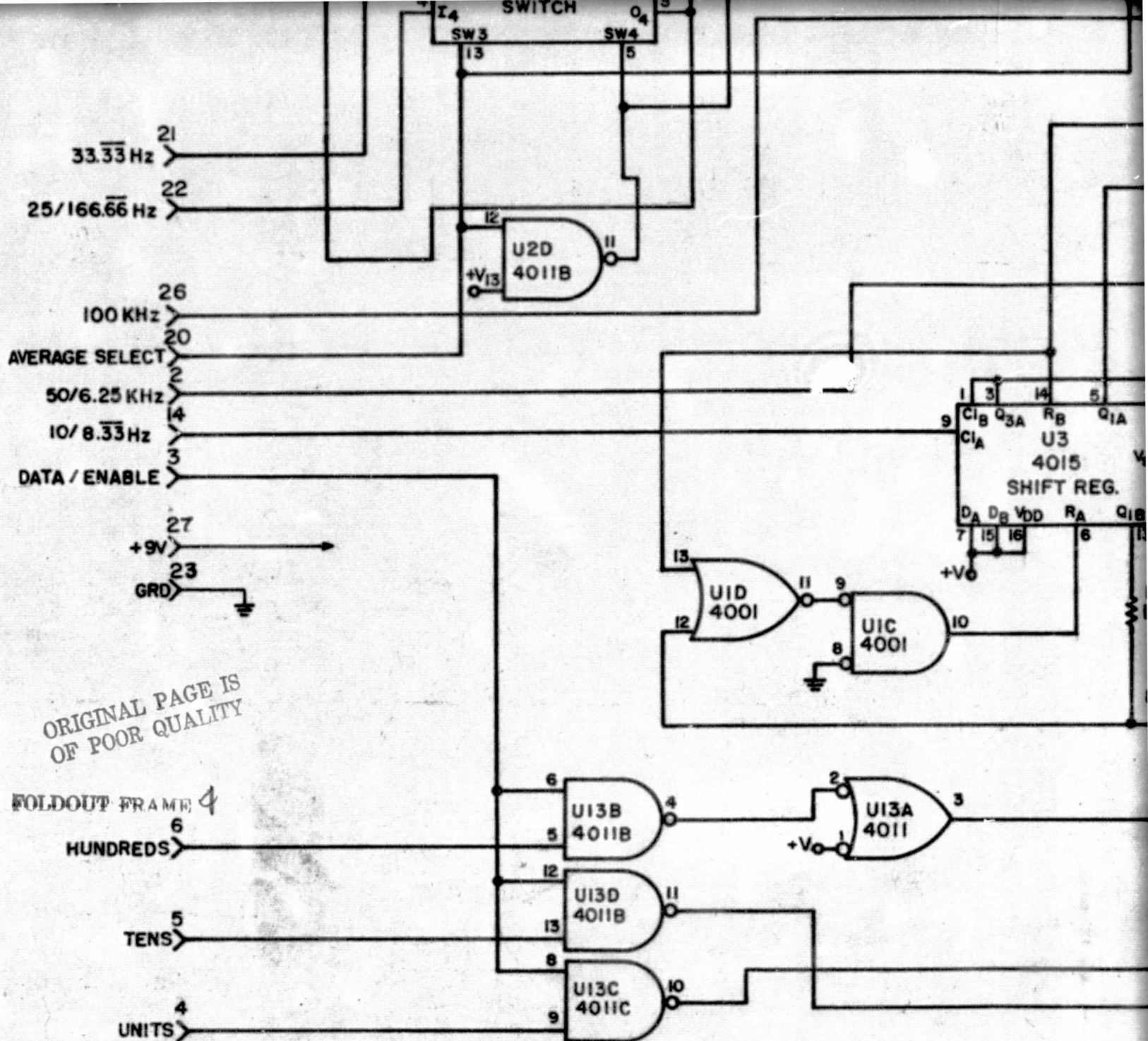
H

J

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FOLDOUT FRAME 3

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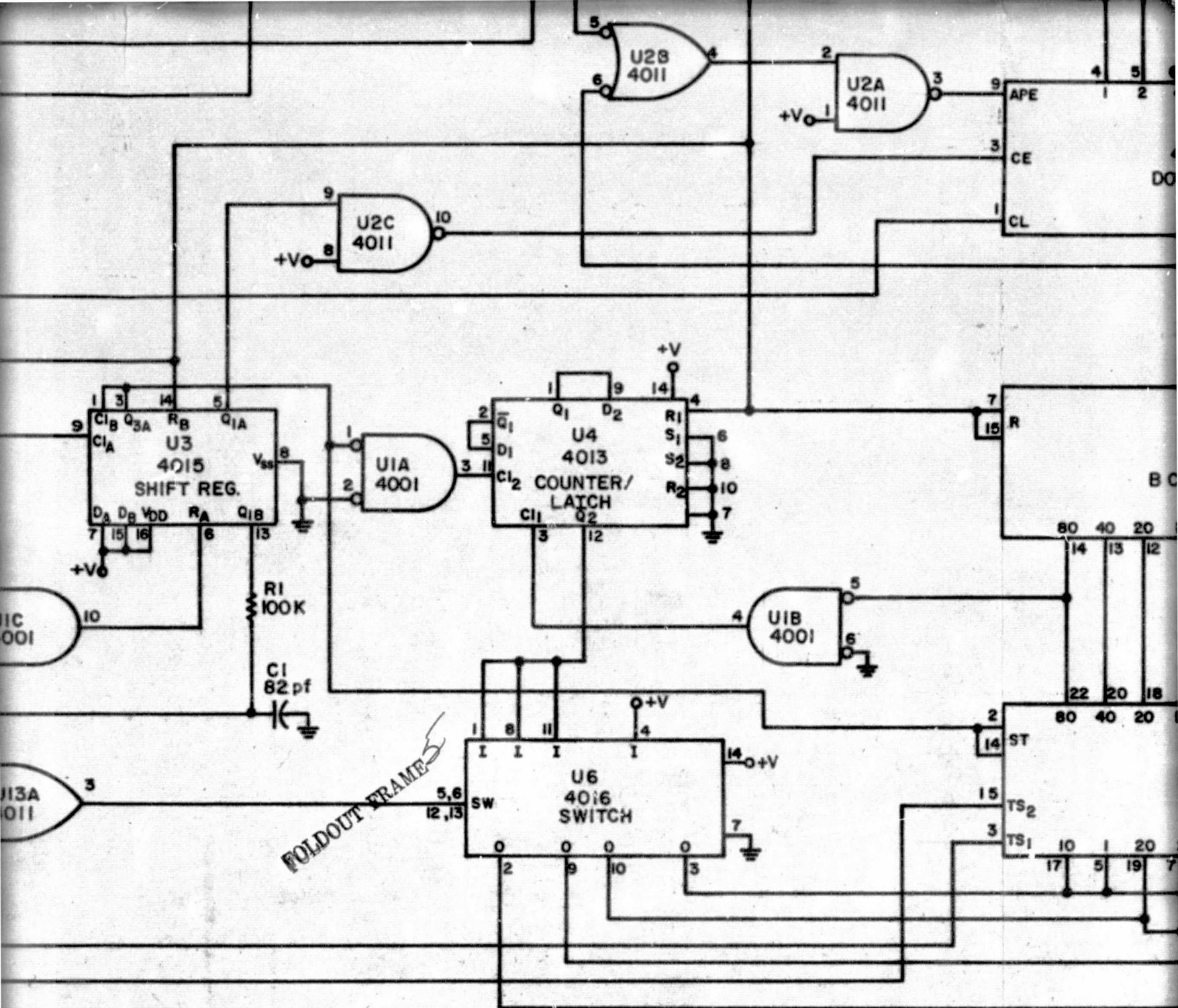
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FOLDOUT FRAME 4

LAST NO. R1, C1, U14

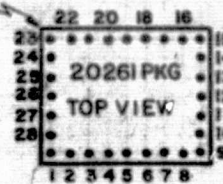
NOTES: FOR HEART PROC.
AVG. SELECT LOW - 1 BEAT AVG.
AVG. SELECT HIGH - 5 BEAT AVG.
FOR BREATH RATE PROC. - AVG. SELECT LOW.

FREQUENCIES USED:	33.33 Hz	166.66 Hz	25 Hz	100 kHz	50K	6.25K	10 Hz	8.33 Hz
BREATH			X	X		X		X
HEART	X	X		X	X		X	



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TOLERANCE
DECIMAL
FRACTION
ANGULAR

ON
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NO

DE

8.33 Hz

X

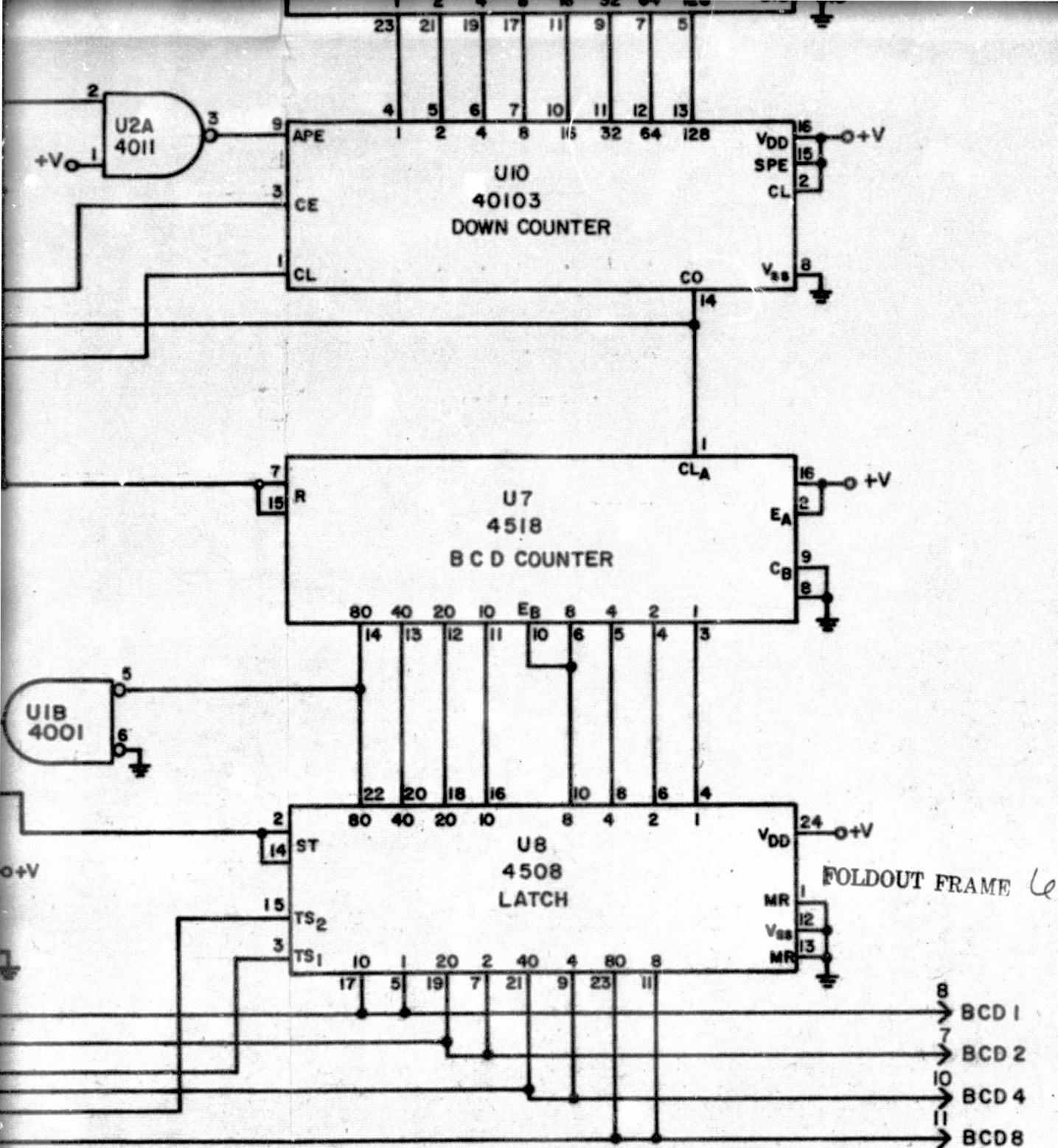
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20 18 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0	UNLESS OTHERWISE SPECIFIED: ALL DIMENSIONS ARE IN INCHES TOLERANCE SHALL BE: DECIMAL DIMENSIONS & FRACTION DIMENSIONS & ANGULAR DIMENSIONS &		TITLE HEART / BREATH RATE PROCESSOR					
	FINISH		MATERIAL 13075 BD.					
	SIGNATURE DATE		ORIGINATED DATE		DRAWN DATE		CHECKED DATE	
	APPROVED DATE		SCALE		EC-13157		DENVER RESEARCH INSTITUTE UNIVERSITY of DENVER	

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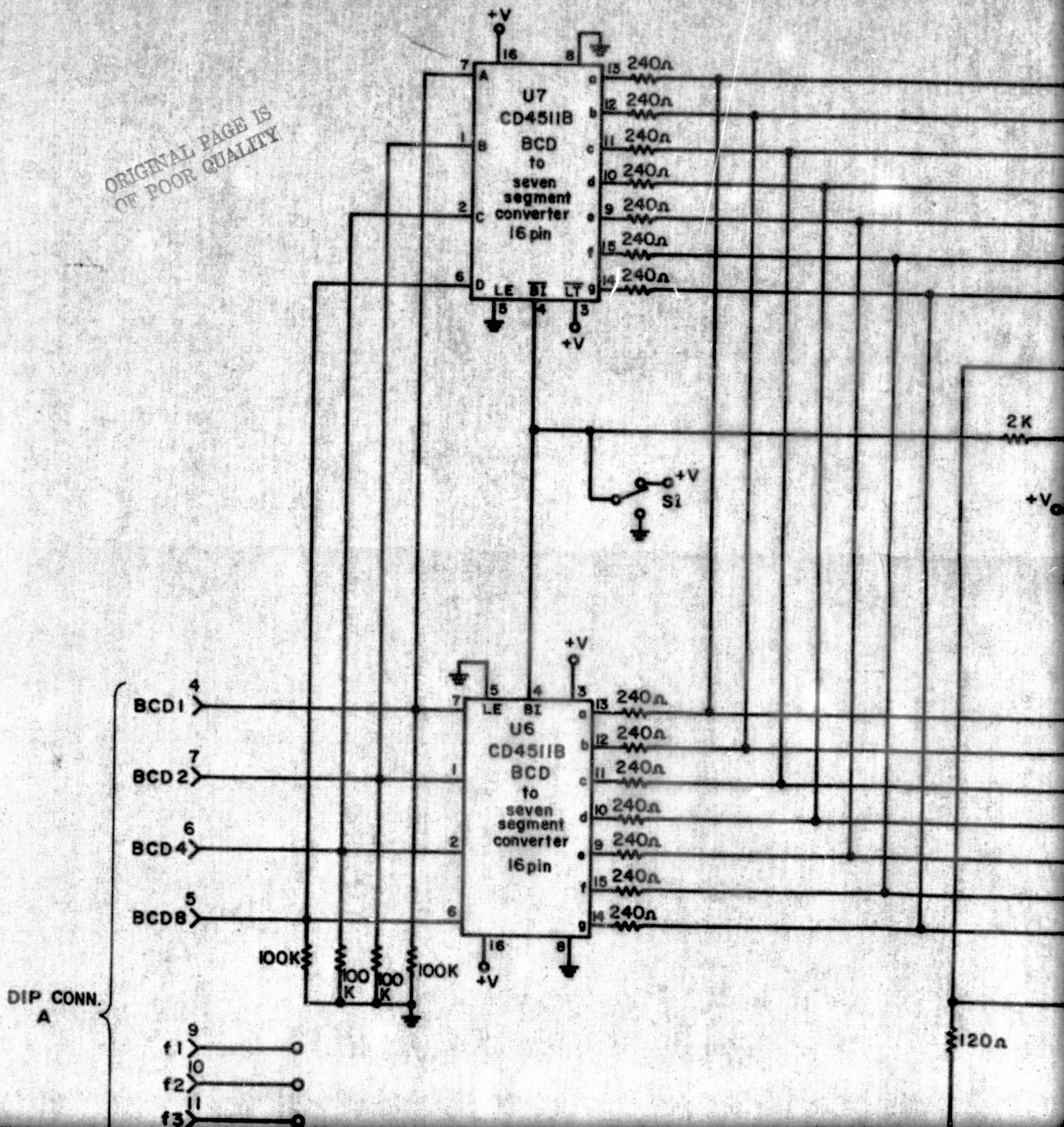
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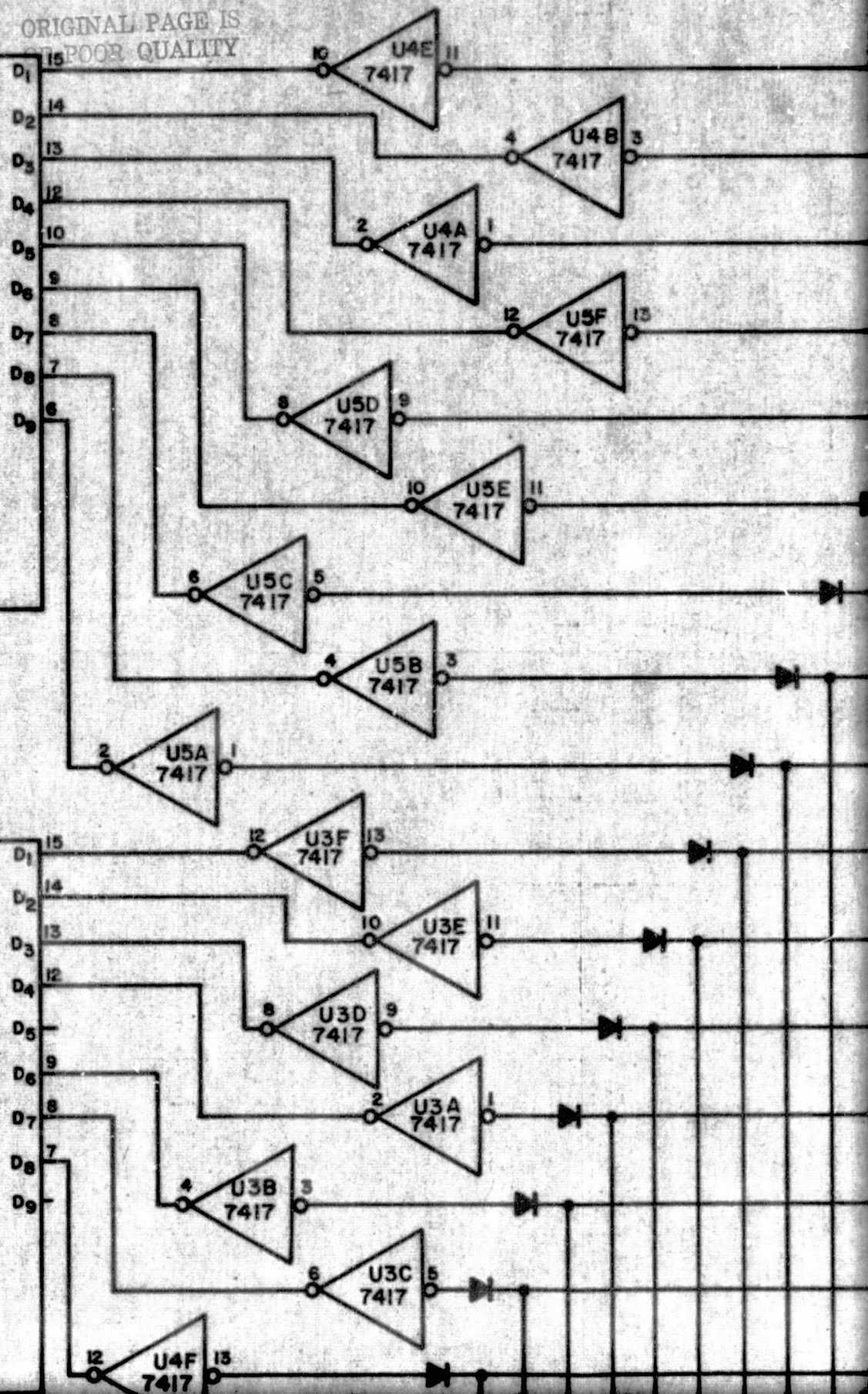
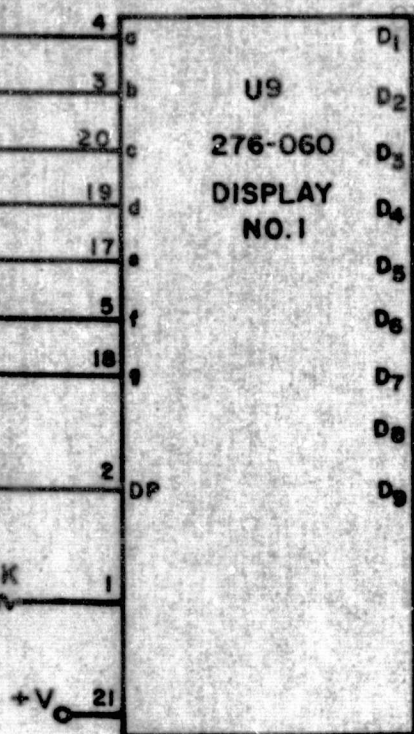
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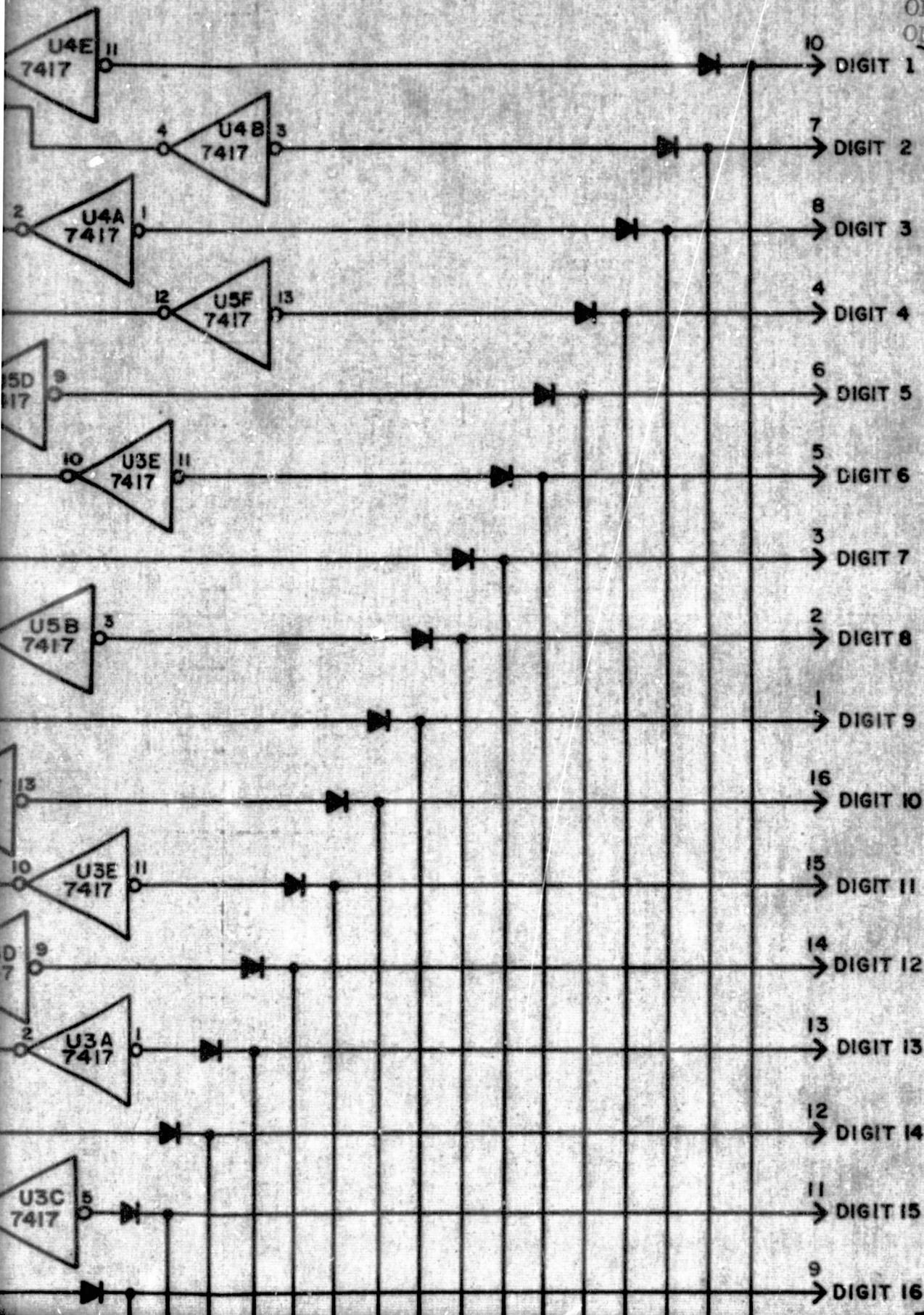
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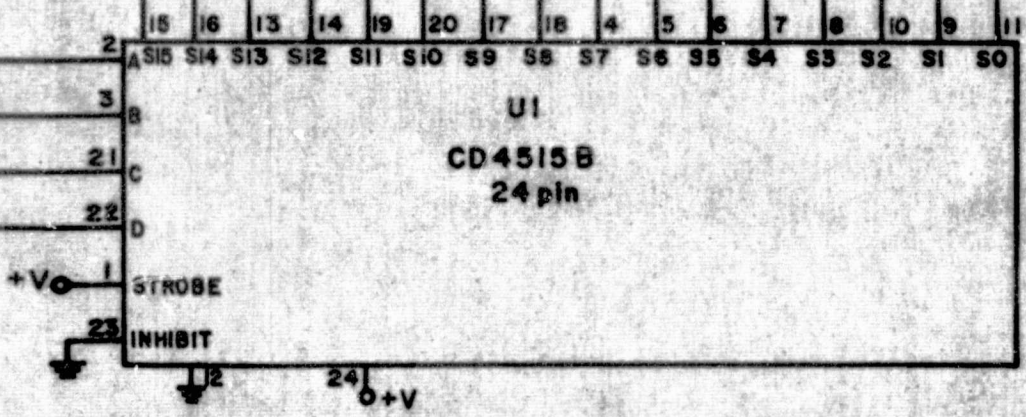
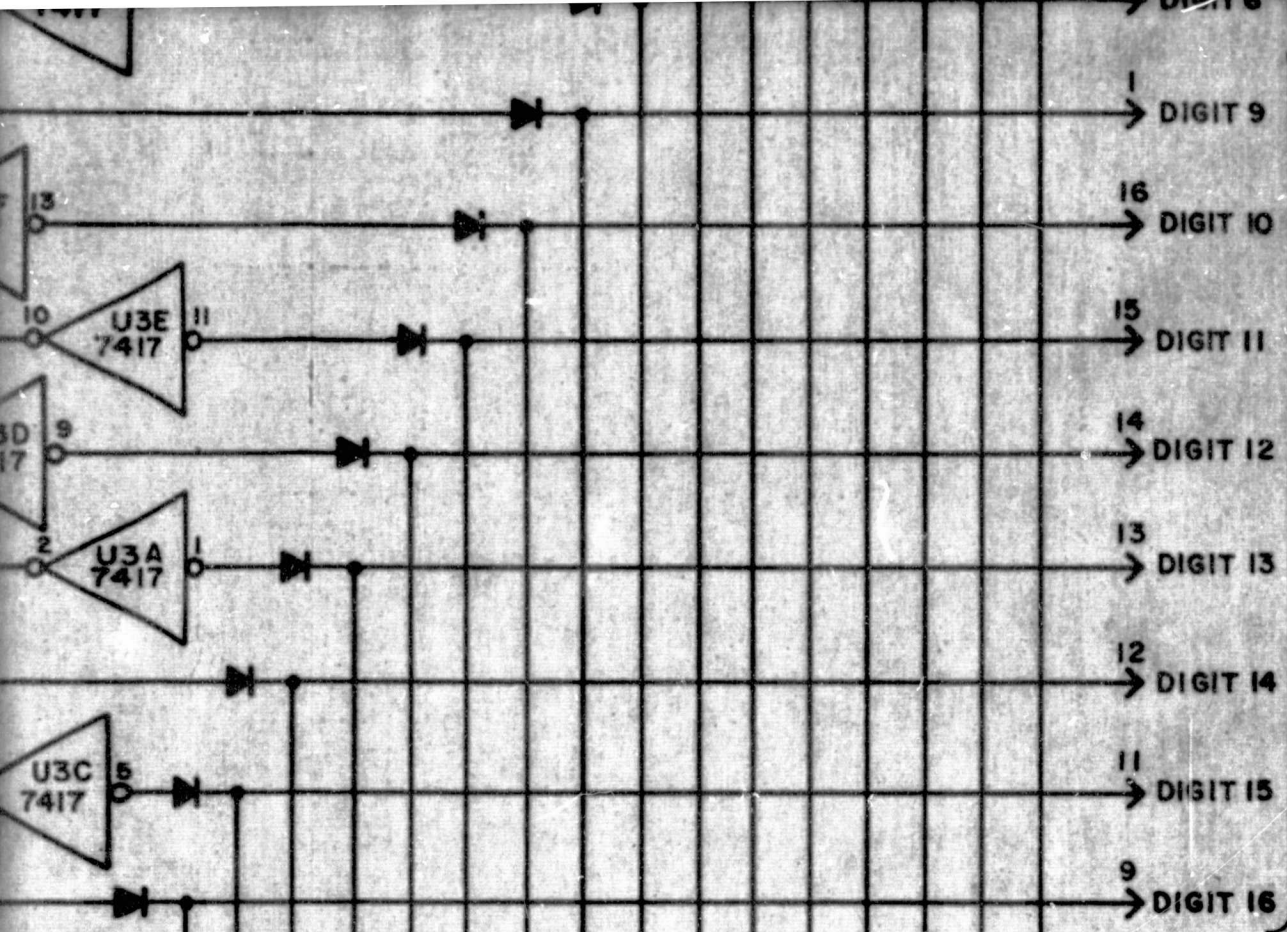
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	FINISH		MATERIAL 13073 BD.				
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	DATE		6-22-77				
DENVER RESEARCH INSTITUTE UNIVERSITY of DENVER							EC-13158

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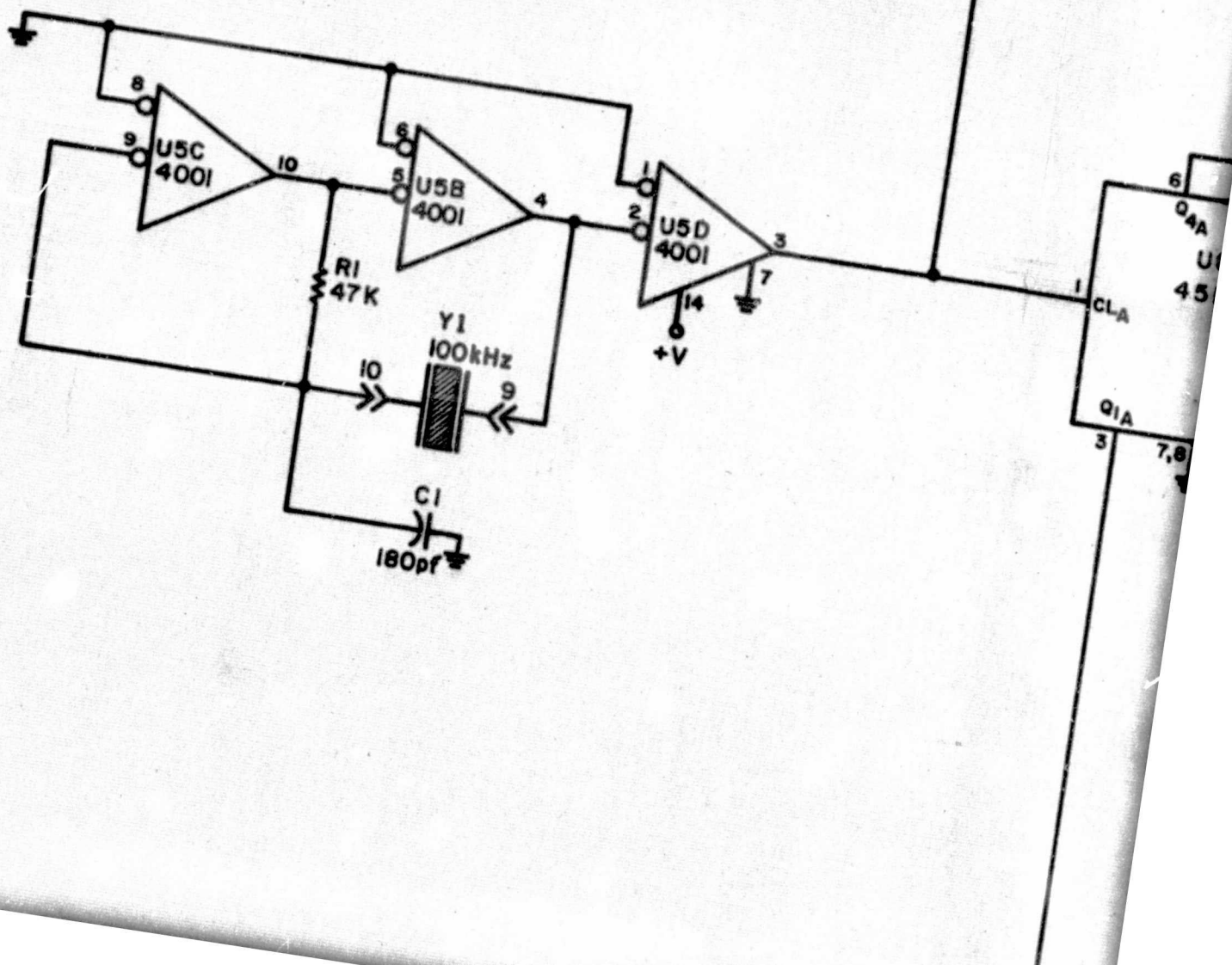
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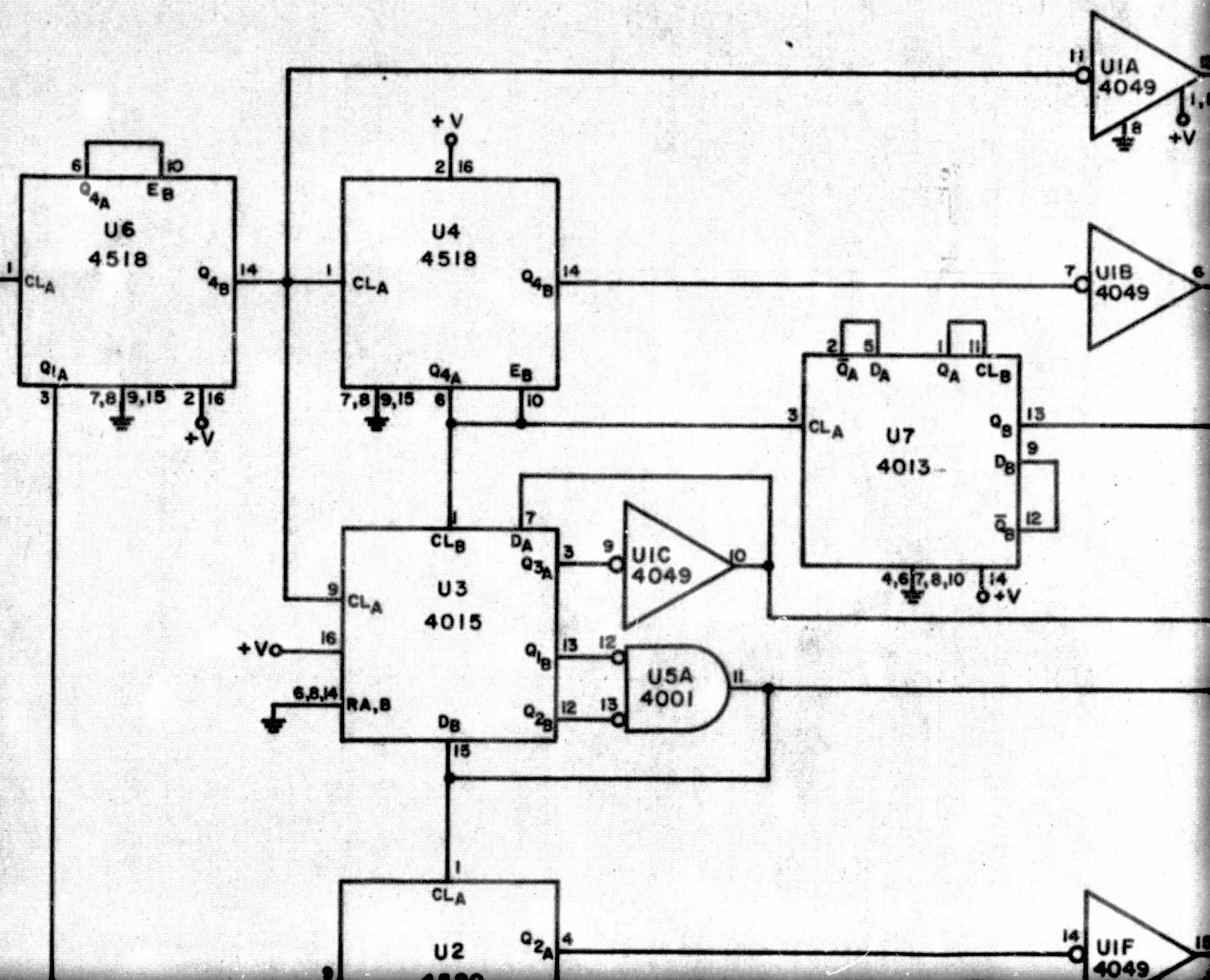
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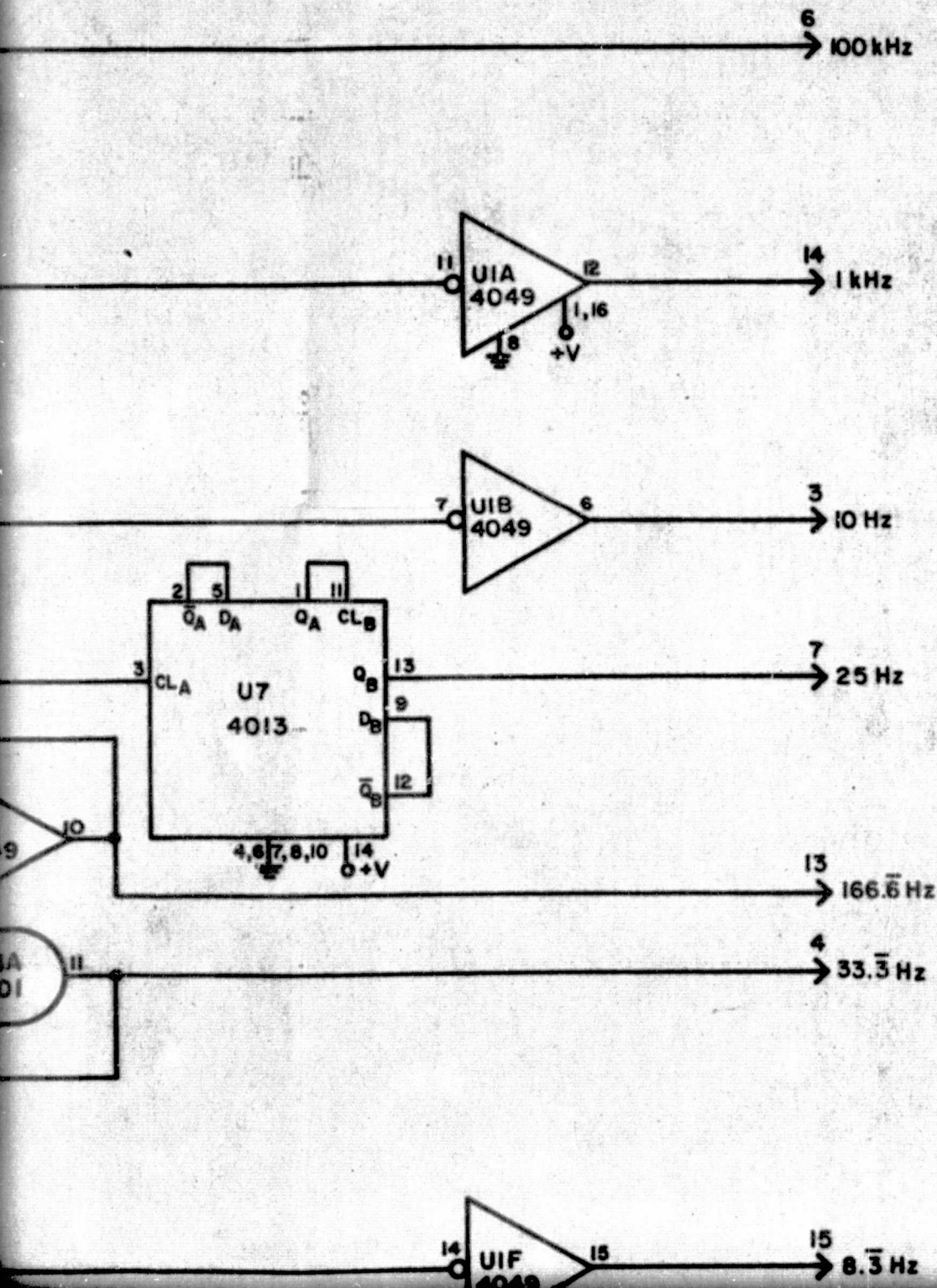
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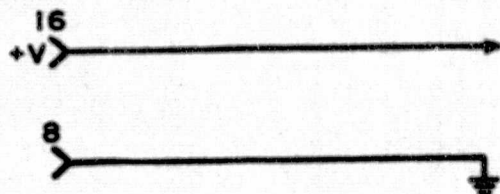
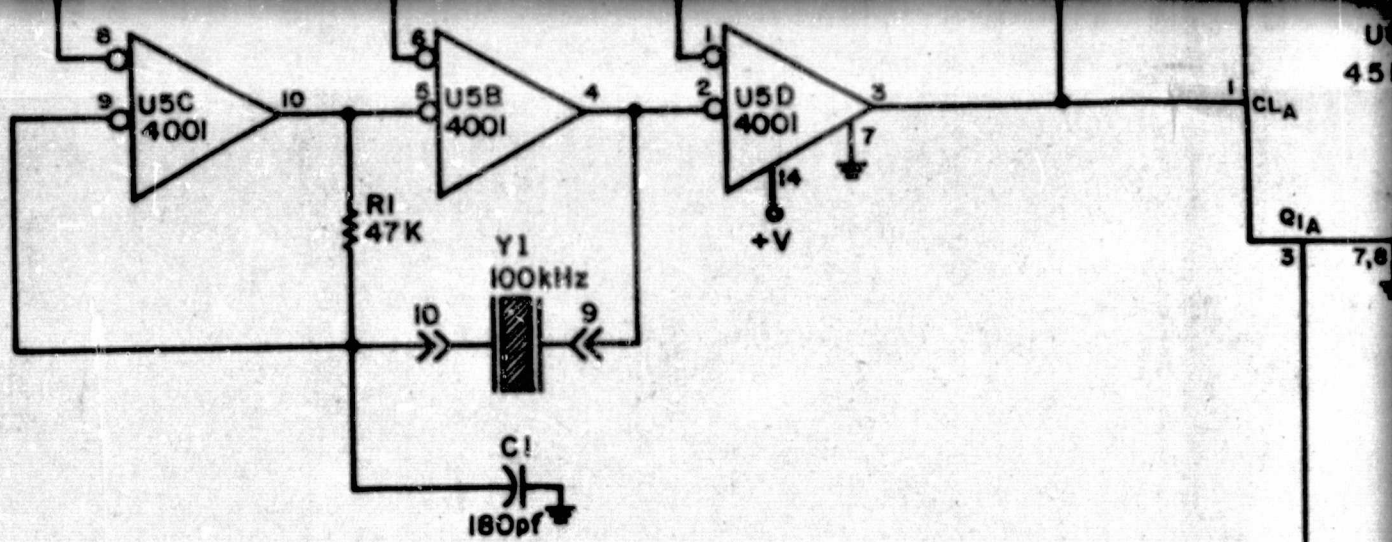
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LAST NO. R1, C1, U7, Y1

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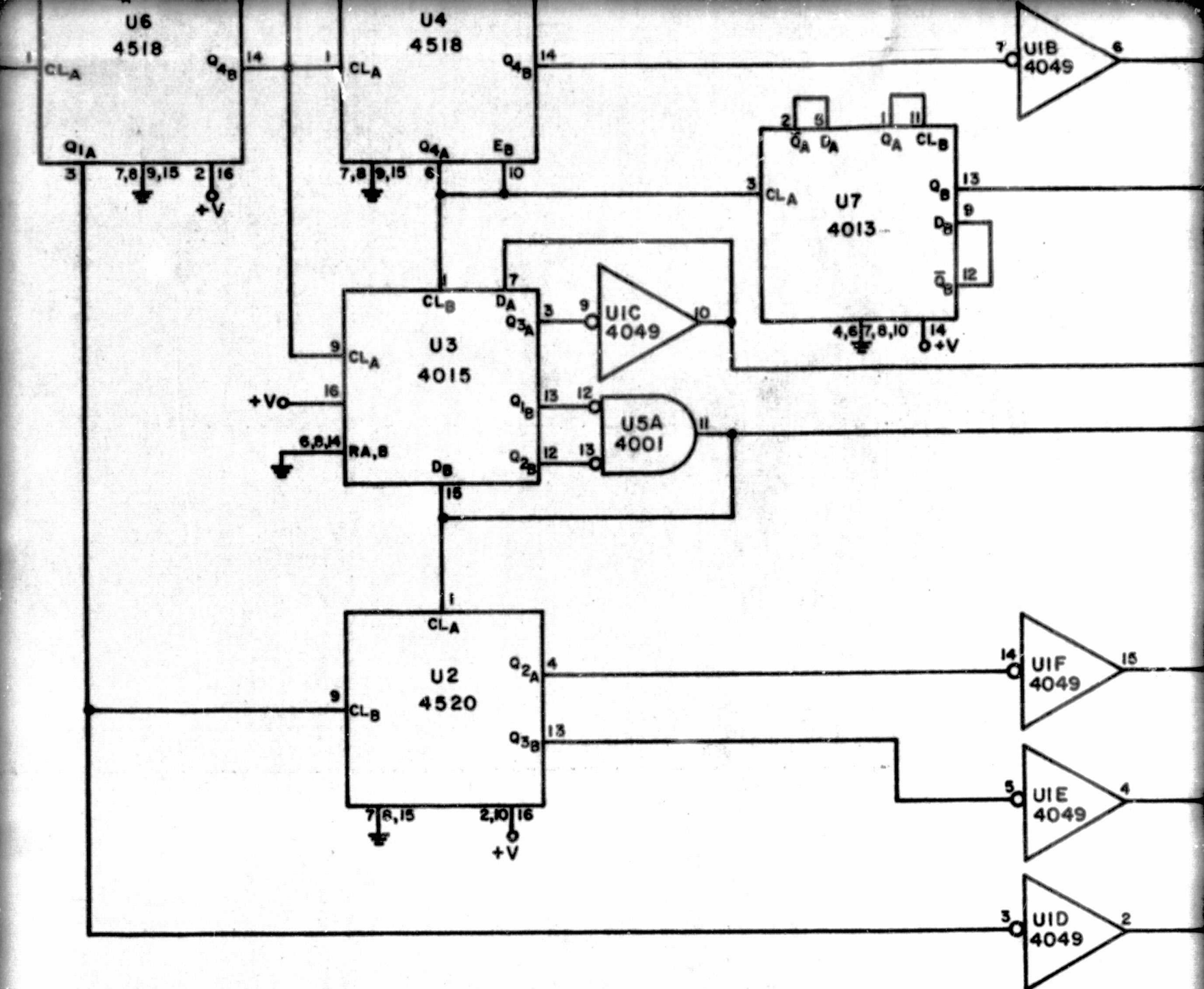
SYM. Dwg. AUTOS-
IZATION NO. DATE APPVD.

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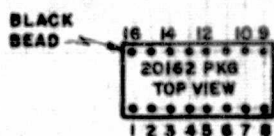
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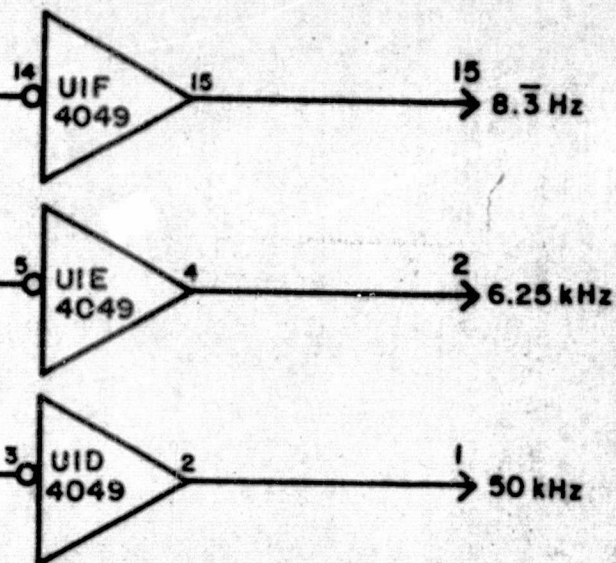
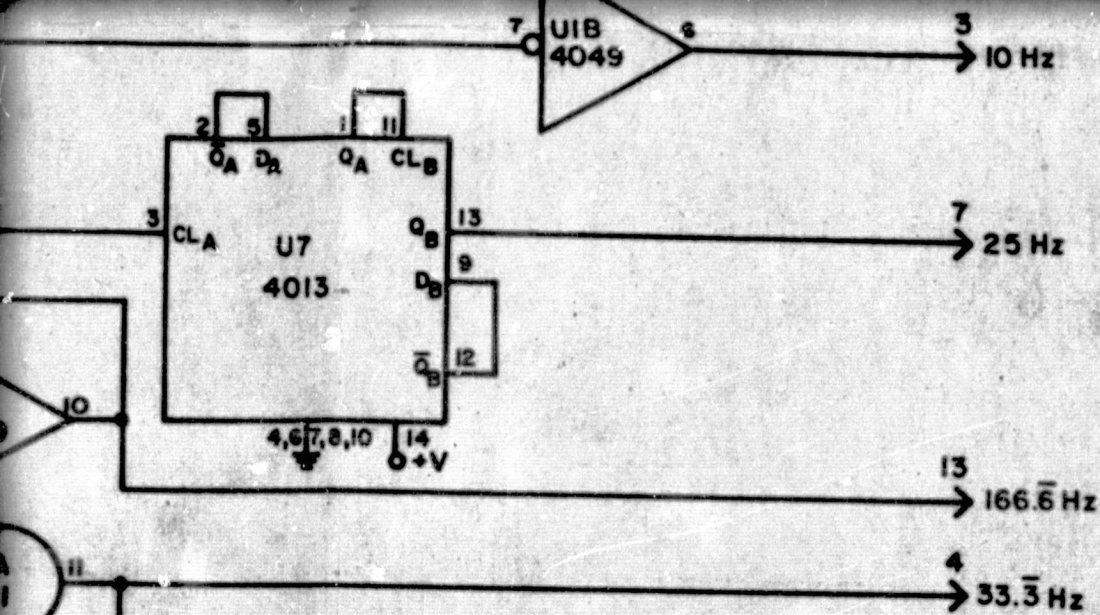
UNLESS OTHERWISE SPECIFIED: ALL DIMENSIONS ARE IN INCHES TOLERANCE SHALL BE— DECIMAL DIMENSIONS ± FRACTION DIMENSIONS ± ANGULAR DIMENSIONS ±	FINISH	MA
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DENVER RESEARCH UNIVERSITY		

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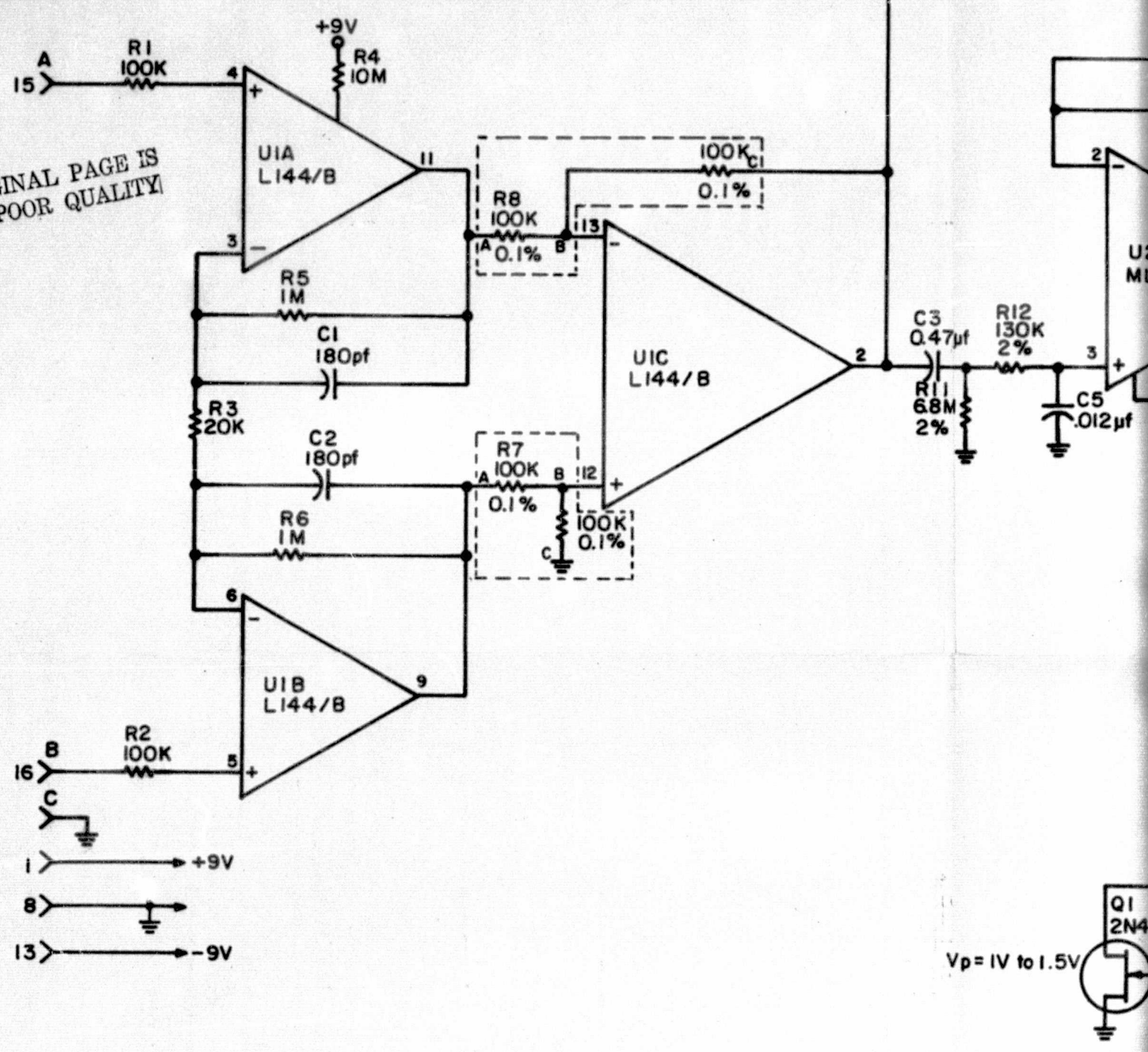
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	MATERIAL 13074 BD.					
FINISH	SIGNATURE	ORIGINATED	DRAWN	CHECKED	APPROVED	SCALE
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DENVER RESEARCH INSTITUTE UNIVERSITY of DENVER				EC-13159		

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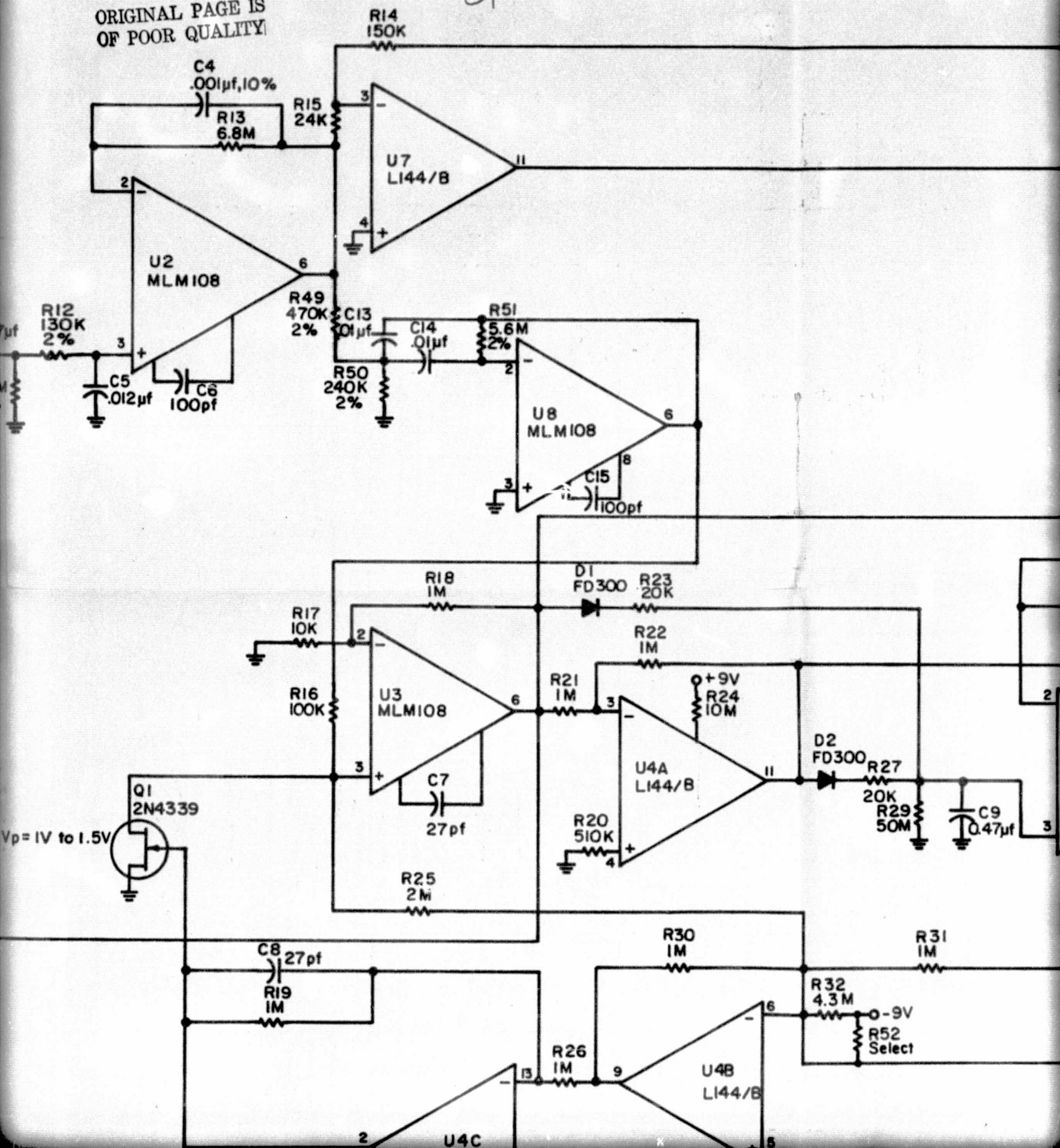
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OF POOR

U2
ML

Q1
2N4

Vp = IV to 1.5V

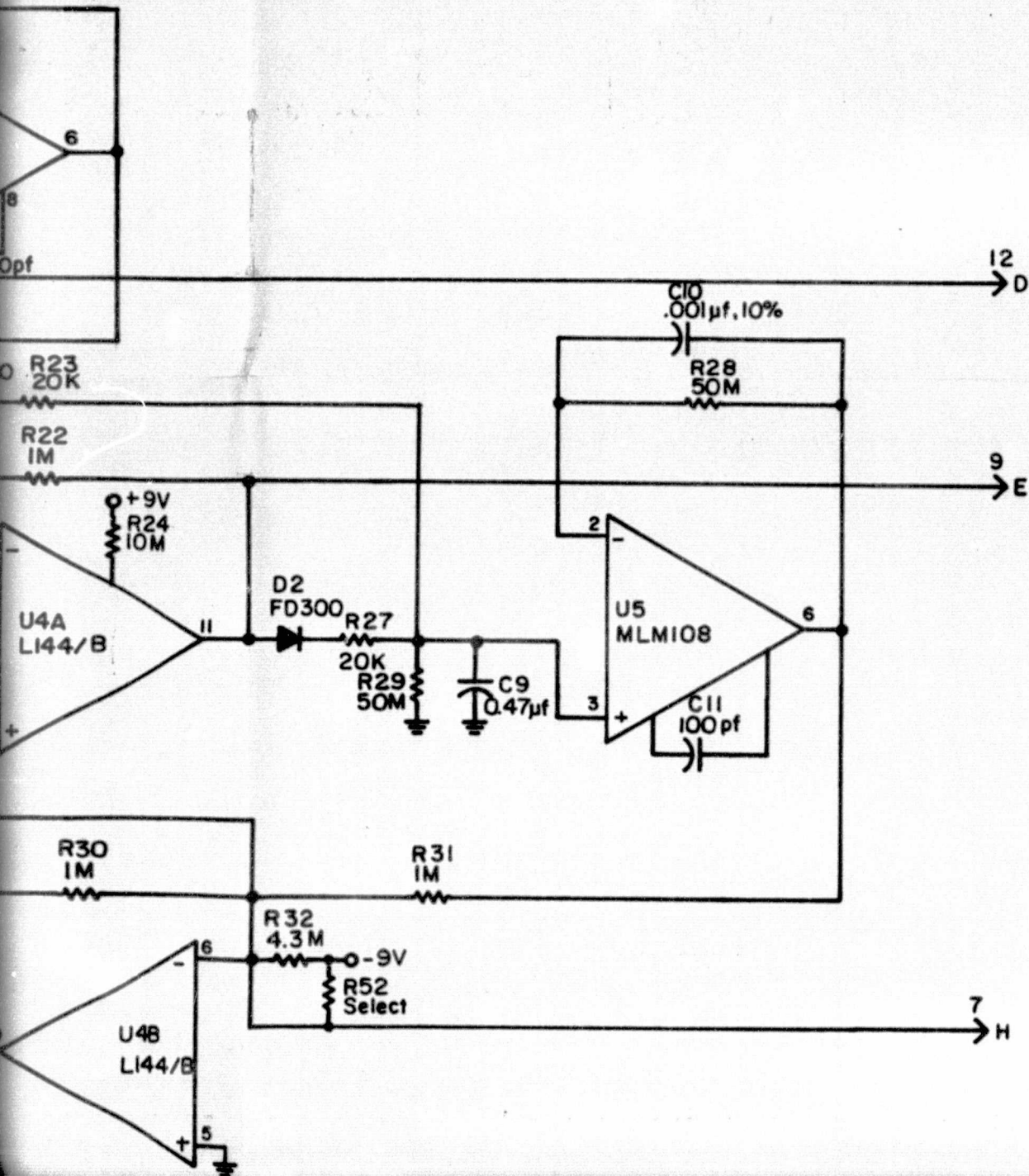
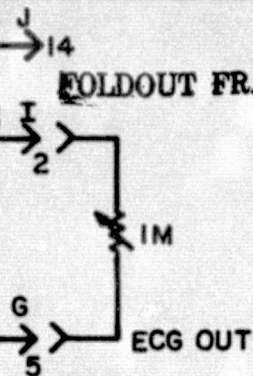
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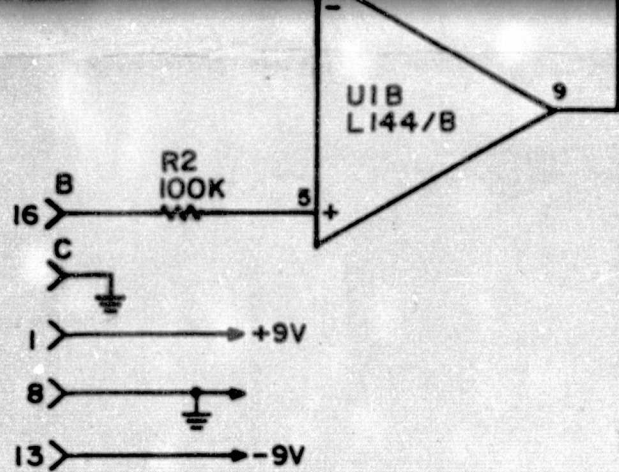


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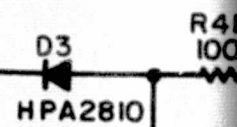
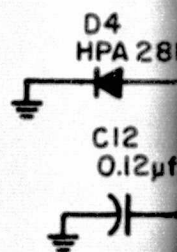
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Vp = IV to 1.5V



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HEART RATE
ALL R
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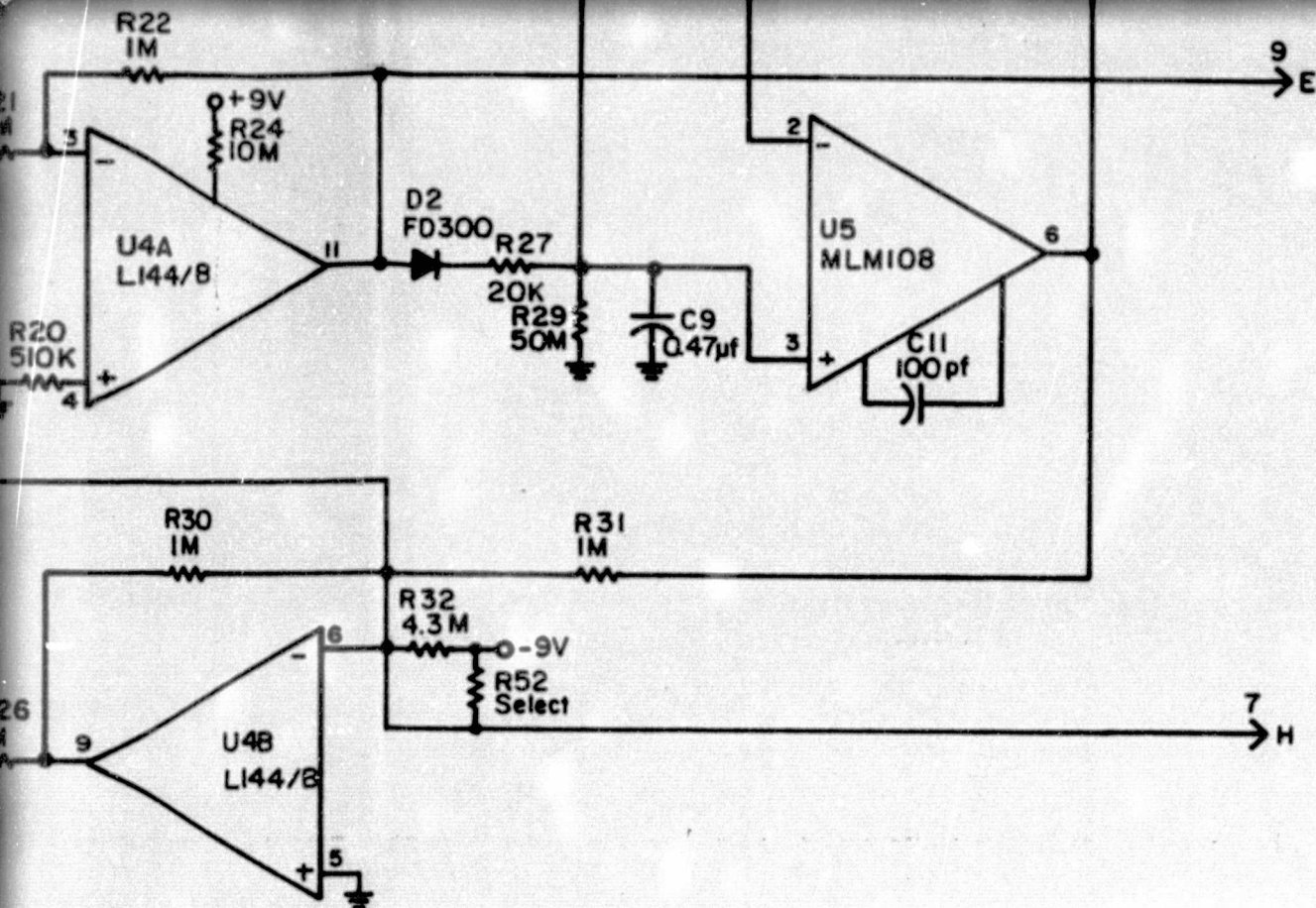
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TO HEART RATE
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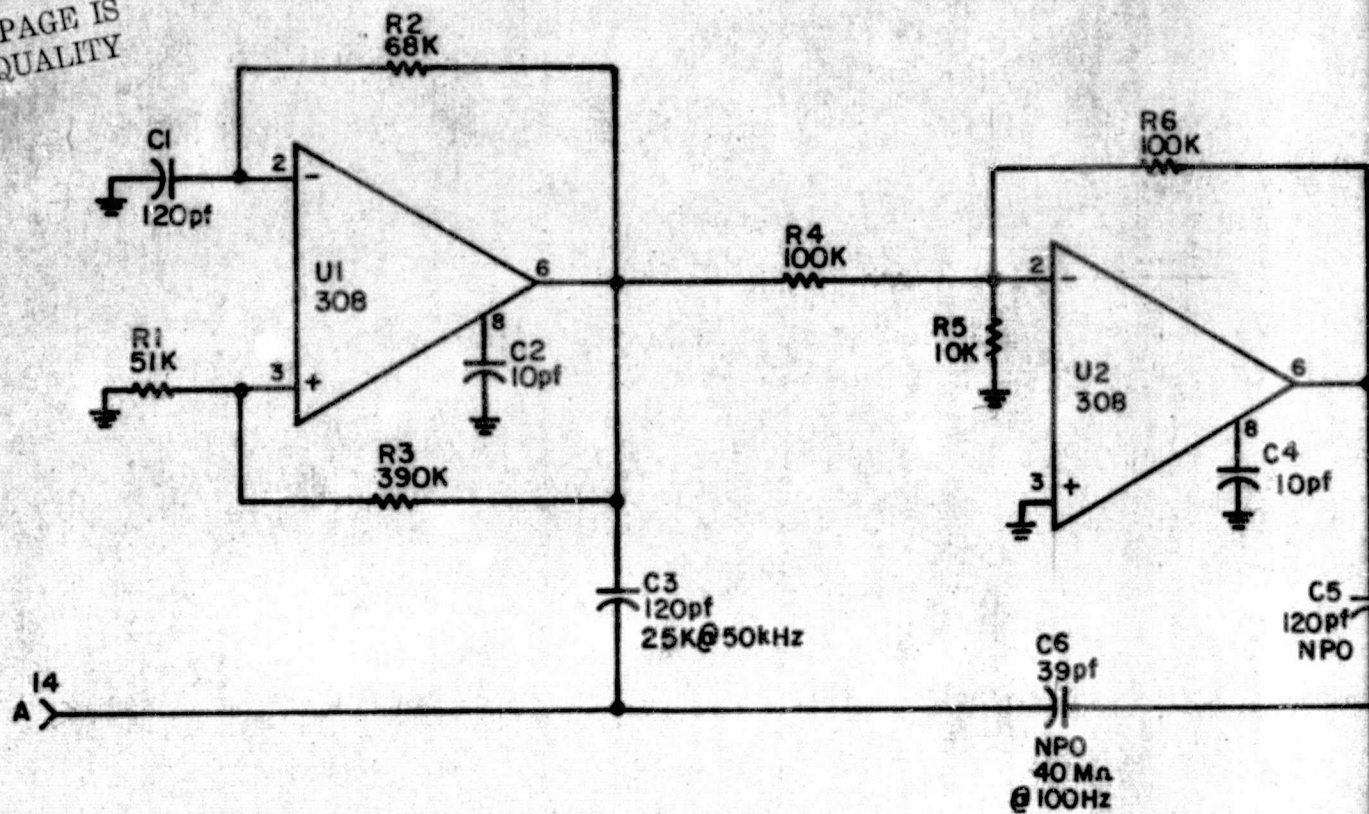
DO NOT SCALE THIS DRAWING



UNLESS OTHERWISE SPECIFIED: ALL DIMENSIONS ARE IN INCHES TOLERANCE SHALL BE: DECIMAL DIMENSIONS ± FRACTION DIMENSIONS ± ANGULAR DIMENSIONS ±	TITLE ECG AMPLIFIER & CARDIOTACHOMETER SIGNAL CONDITIONER					
	MATERIAL					
	SIGNATURE	ORIGINATED	DRAWN	CHECKED	APPROVED	SCALE
	DATE	7-13-77	7-13-77			
DENVER RESEARCH INSTITUTE UNIVERSITY of DENVER						EC-13257

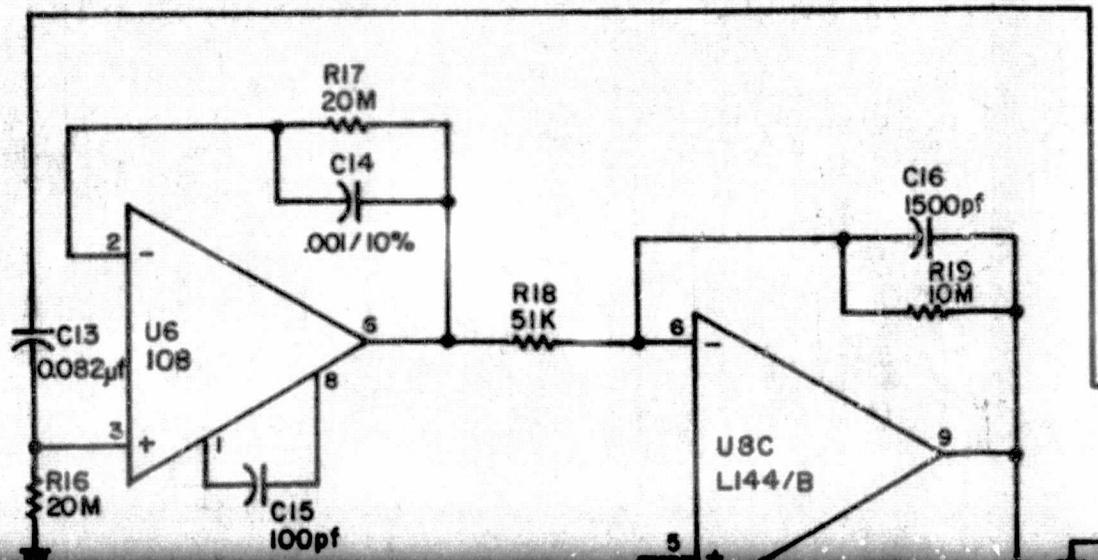
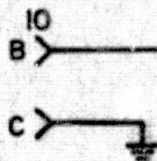
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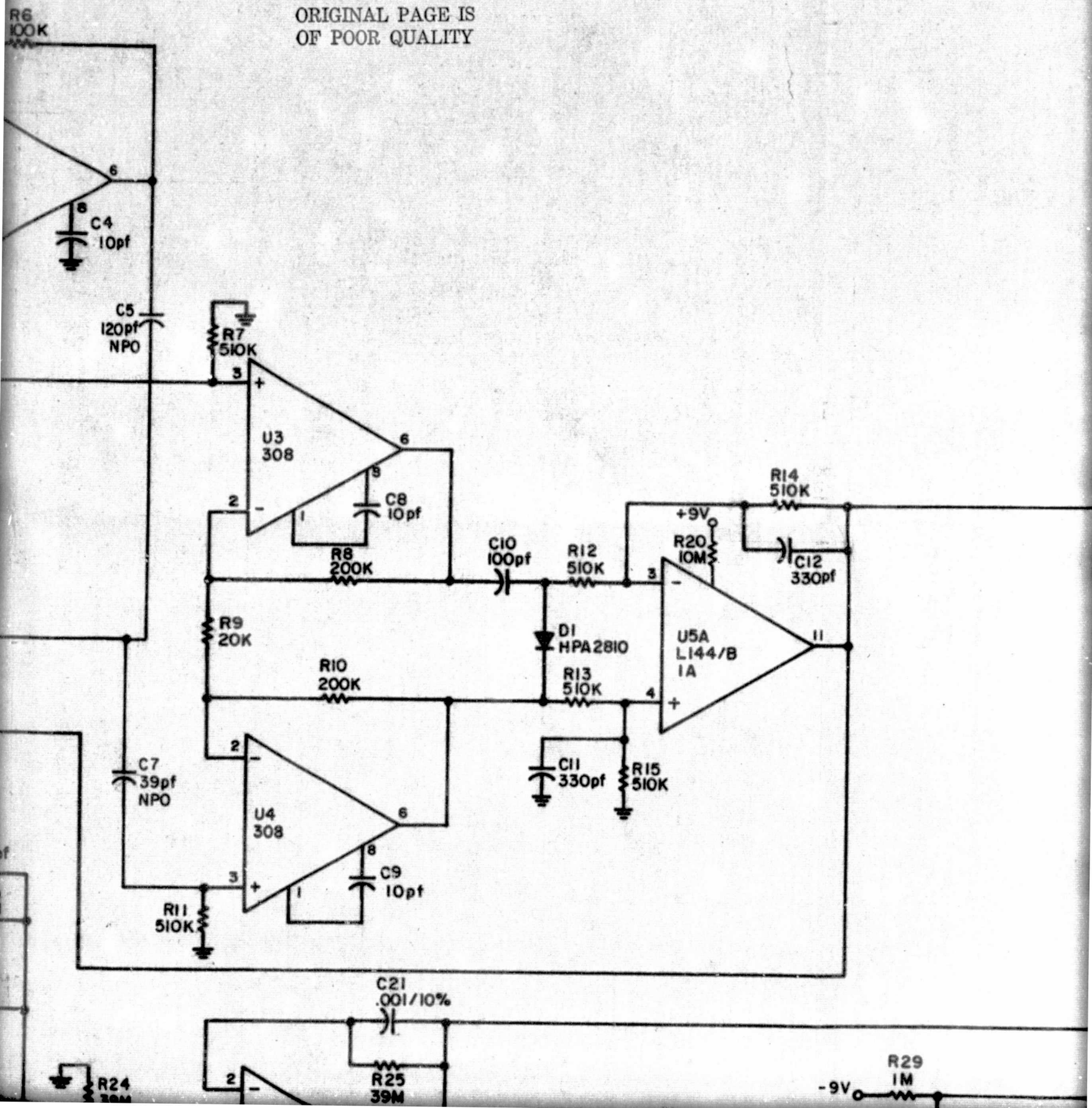
$$100 - 1000 \Omega = Z_0$$

BREATH RATE 6/min to 24/min



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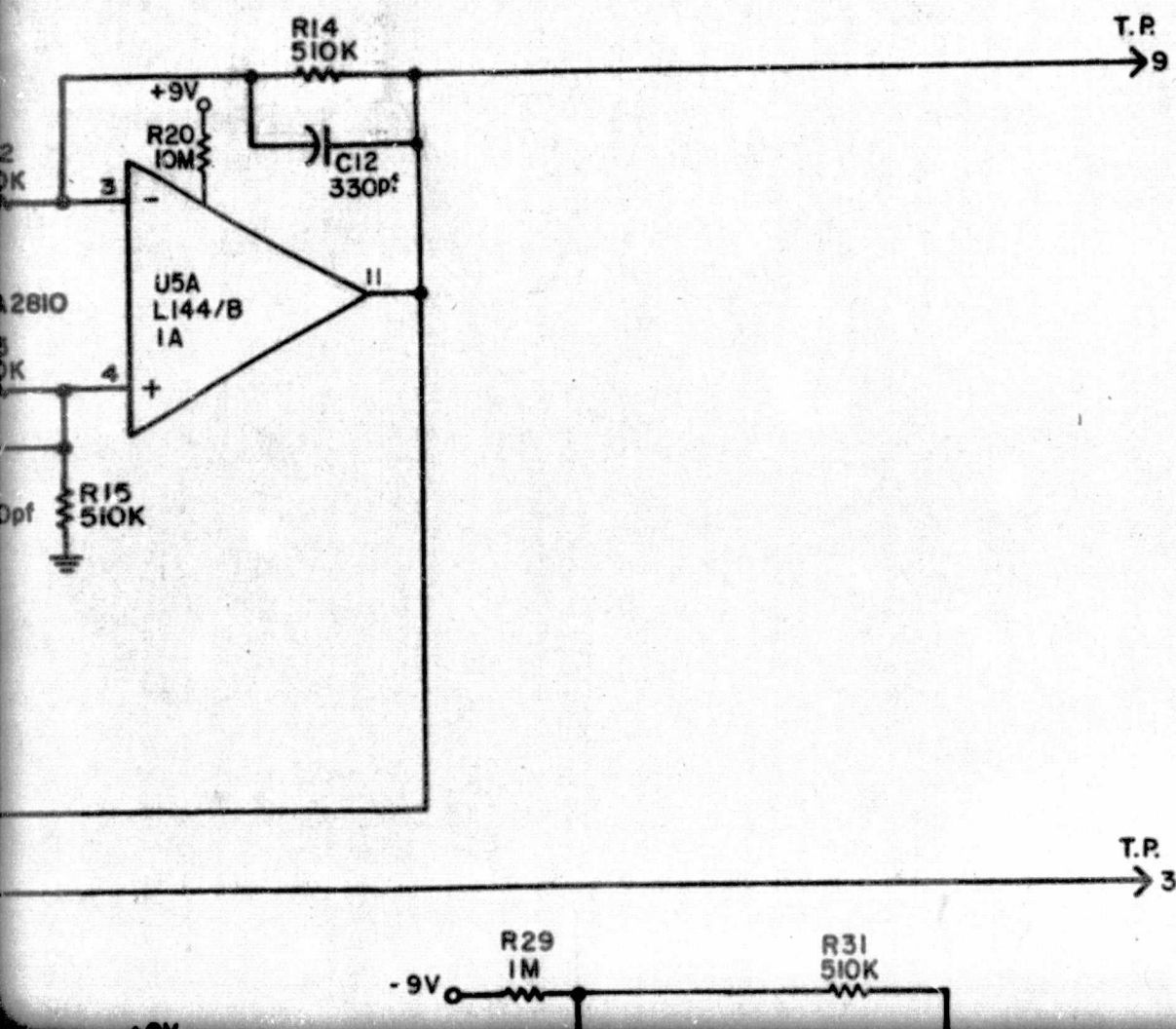
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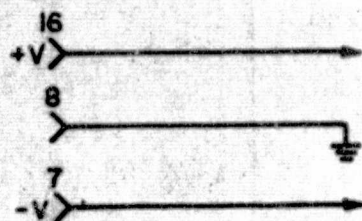
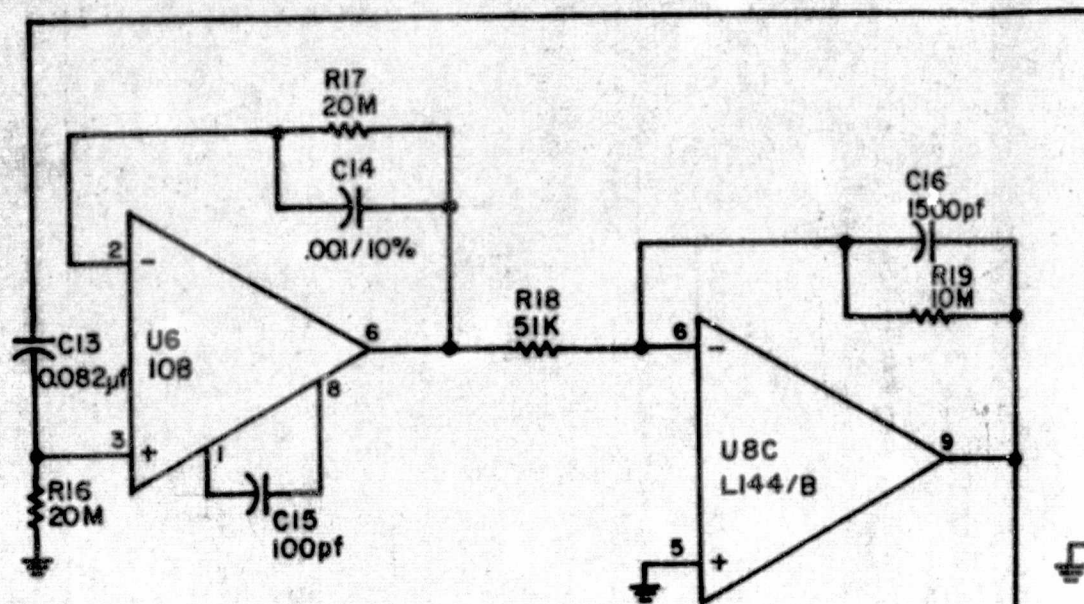
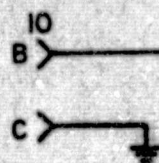
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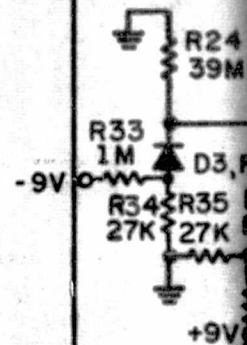
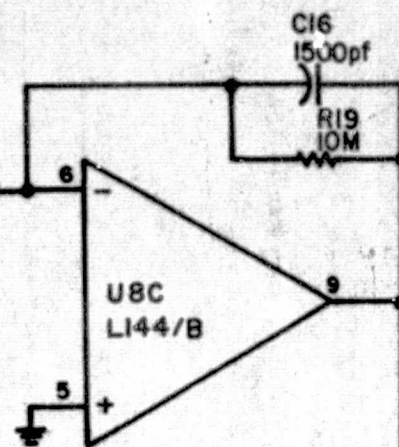
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100 - 1000 Ω = Z_0

BREATH RATE 6/min to 24/min



LAST NO. R36, C21, D4, U8
ALL RESISTORS & CAPACITORS $\pm 5\%$
UNLESS OTHERWISE NOTED.



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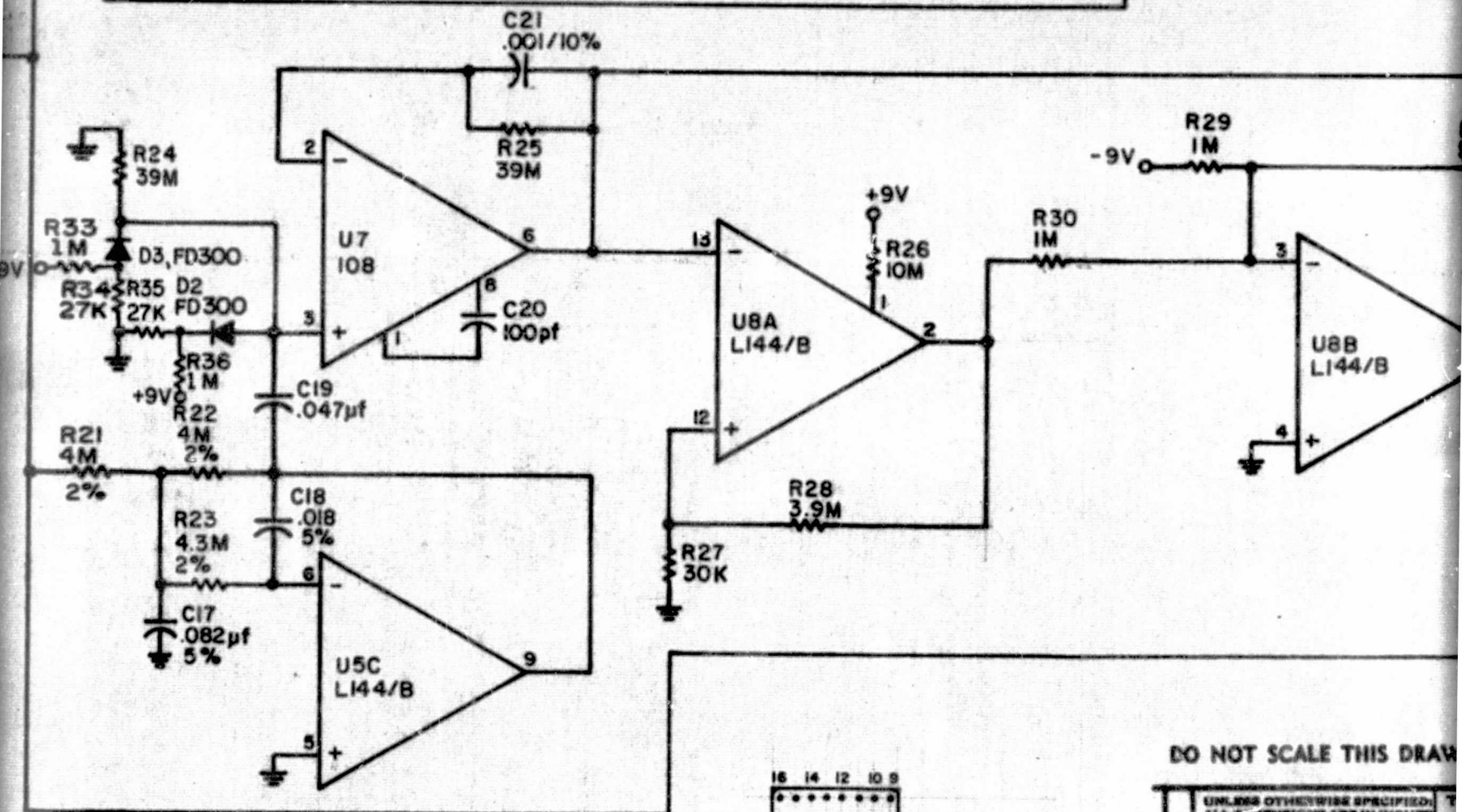
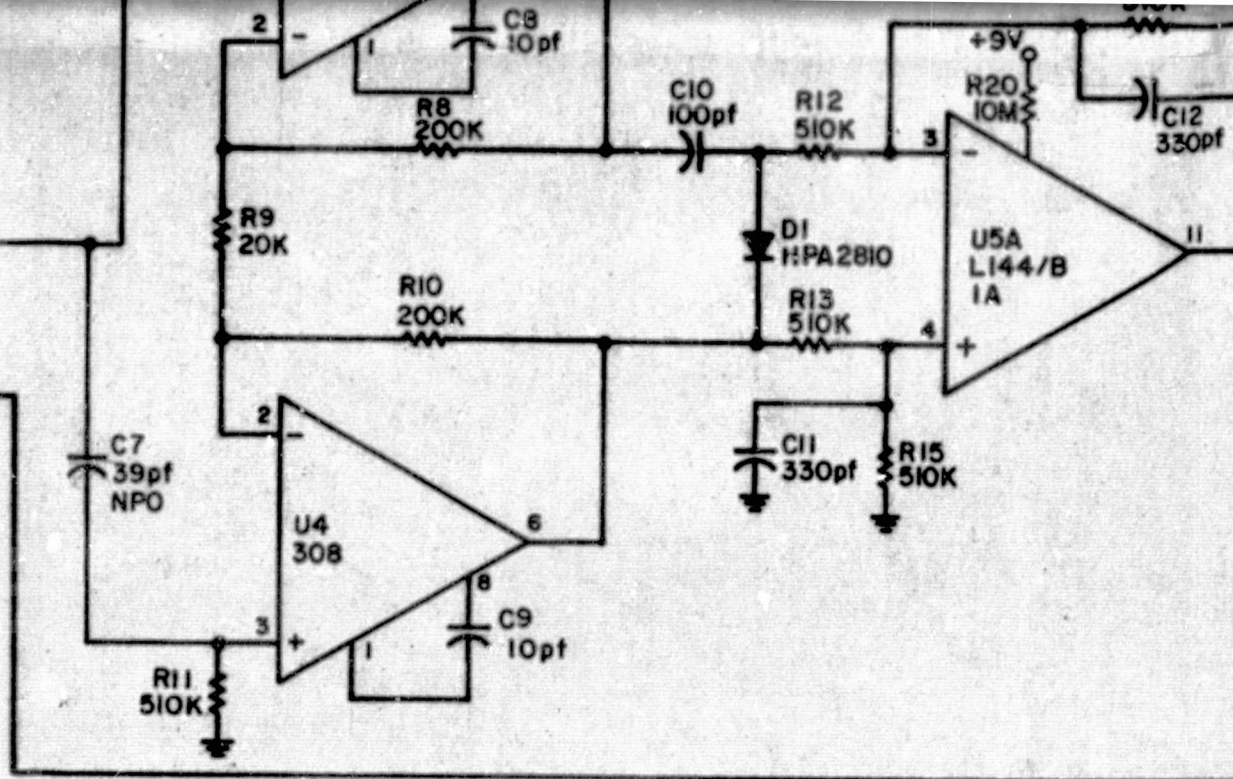
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DES. AUTH. DATE
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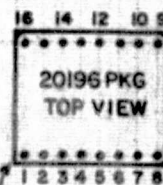
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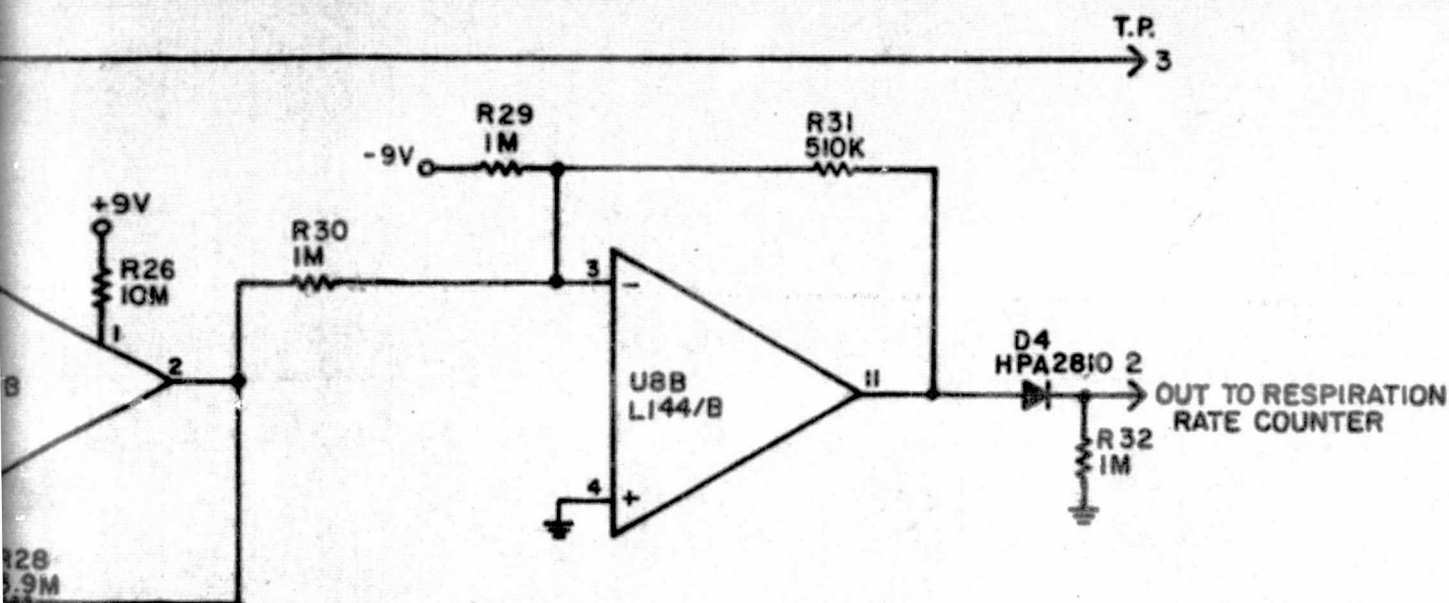
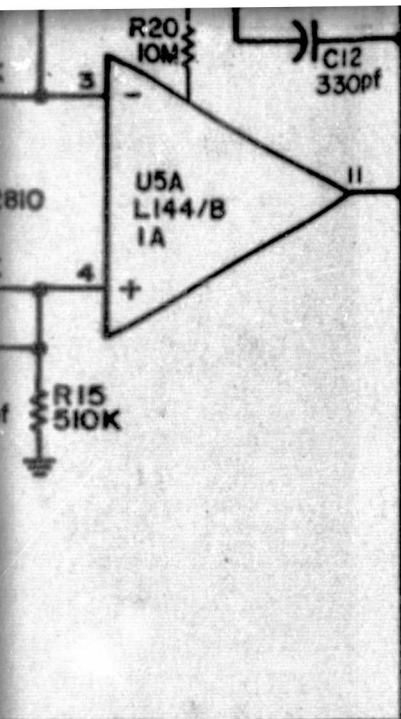
FOLDOUT FRAME 5

SQUARE
CORNER



DO NOT SCALE THIS DRAWING

Q15 USED	UNLESS OTHERWISE SPECIFIED: ALL DIMENSIONS ARE IN INCHES TOLERANCE SHALL BE: DECIMAL DIMENSIONS ± FRACTION DIMENSIONS ± ANGULAR DIMENSIONS ±	
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T.P. 2 → IMPEDANCE PNEUMOGRAPH
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14 12 10 8
0196 PKG
TOP VIEW
3 4 5 6 7 8

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	FINISH	MATERIAL					
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DENVER RESEARCH INSTITUTE UNIVERSITY of DENVER						EC-13268	

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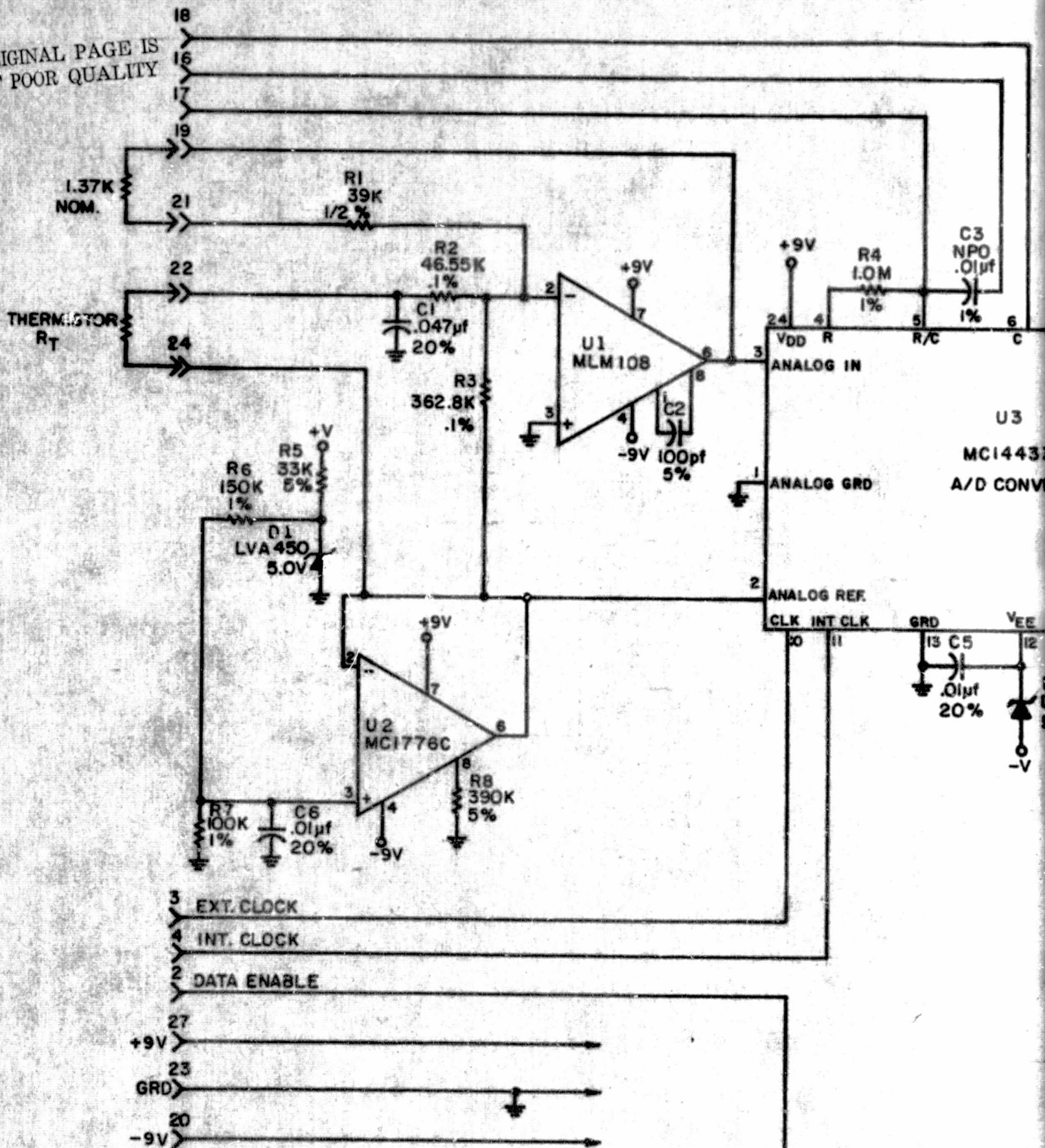
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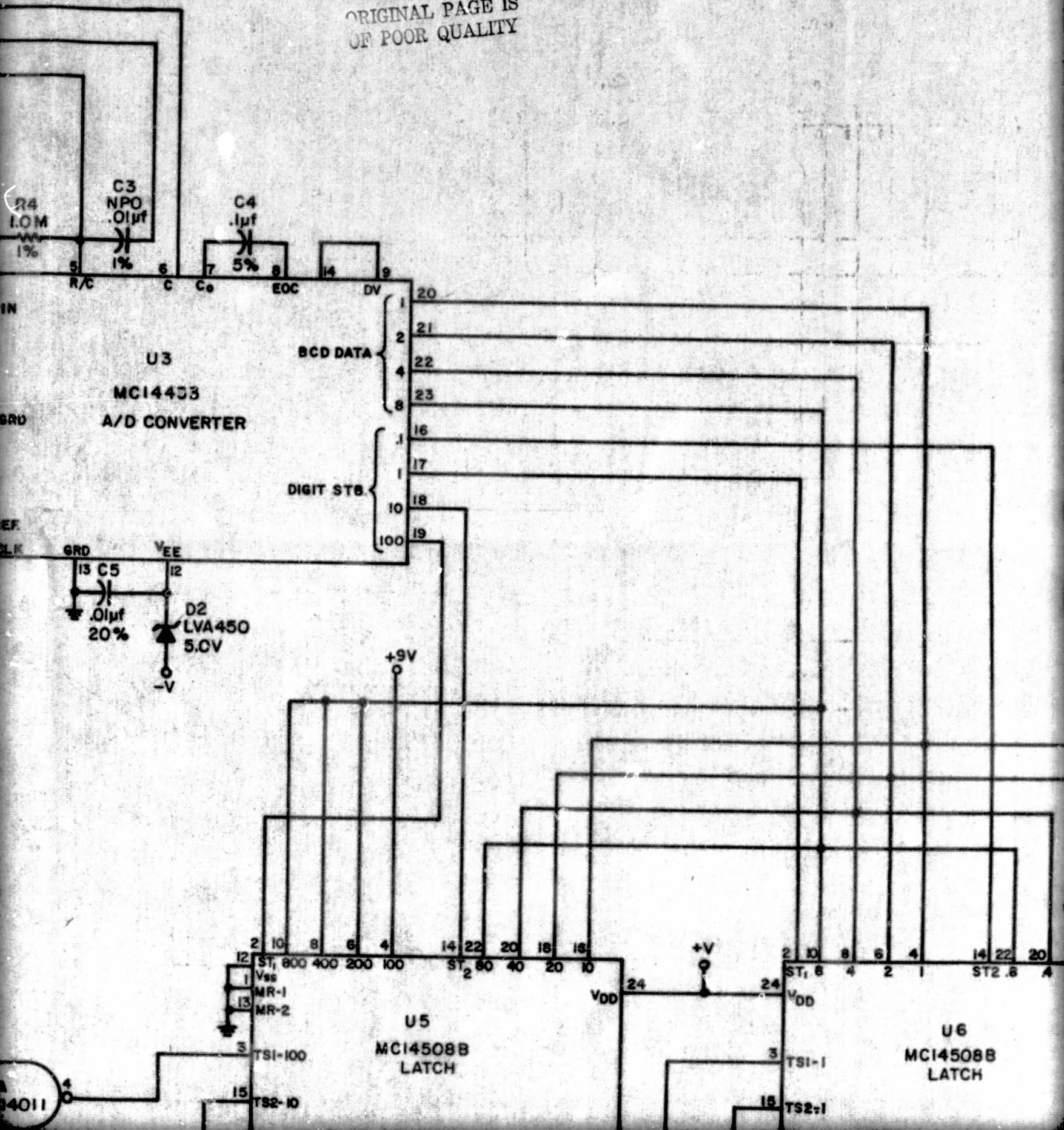
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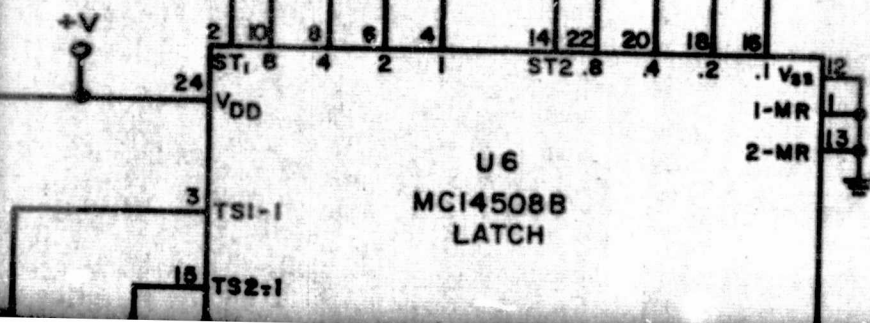
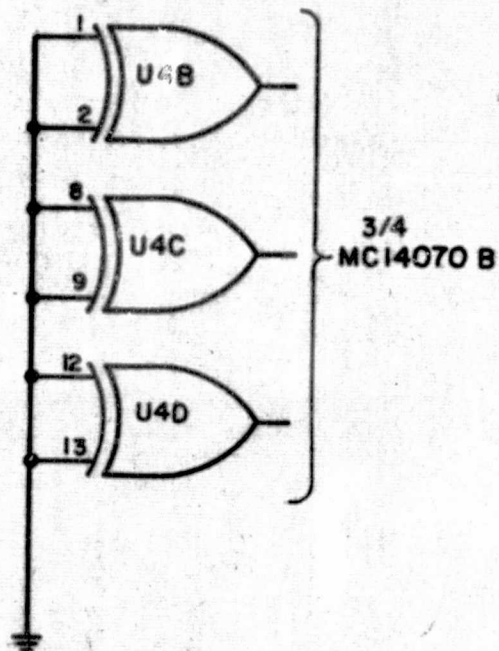
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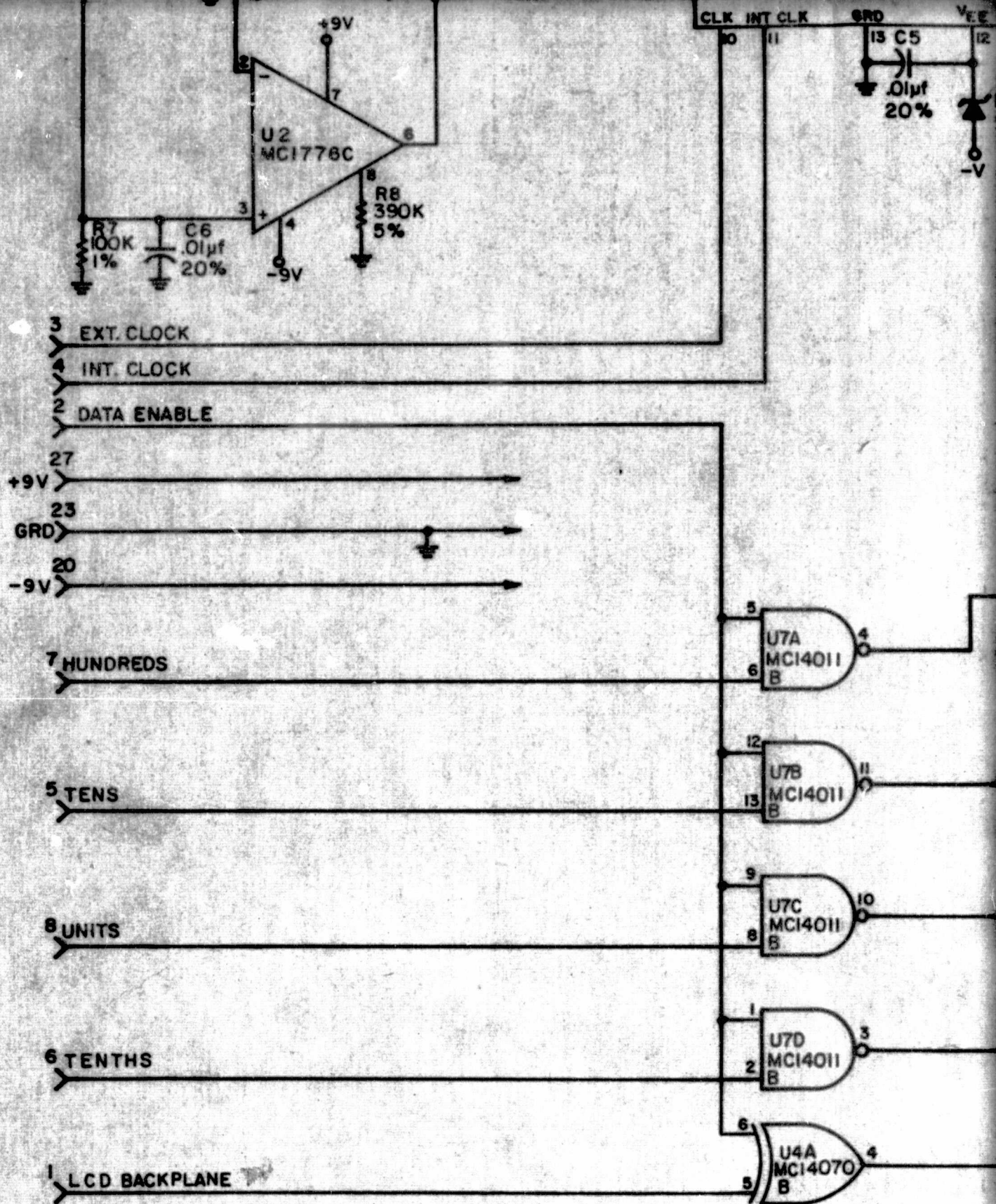
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LAST VALUES R8, C6, D2, U7

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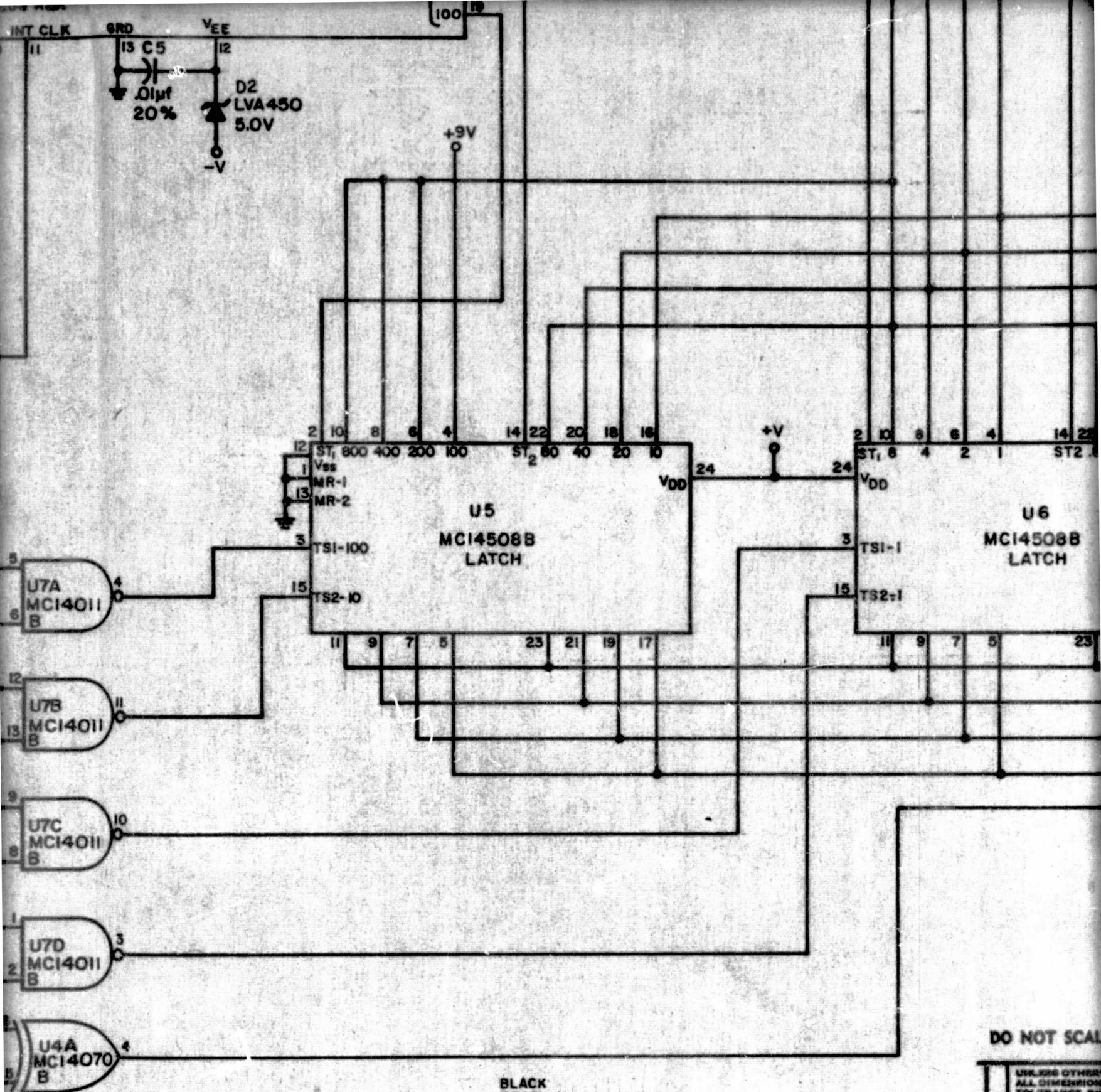
SYM. DATE APPR. REV. AUTOM. IZATION NO.

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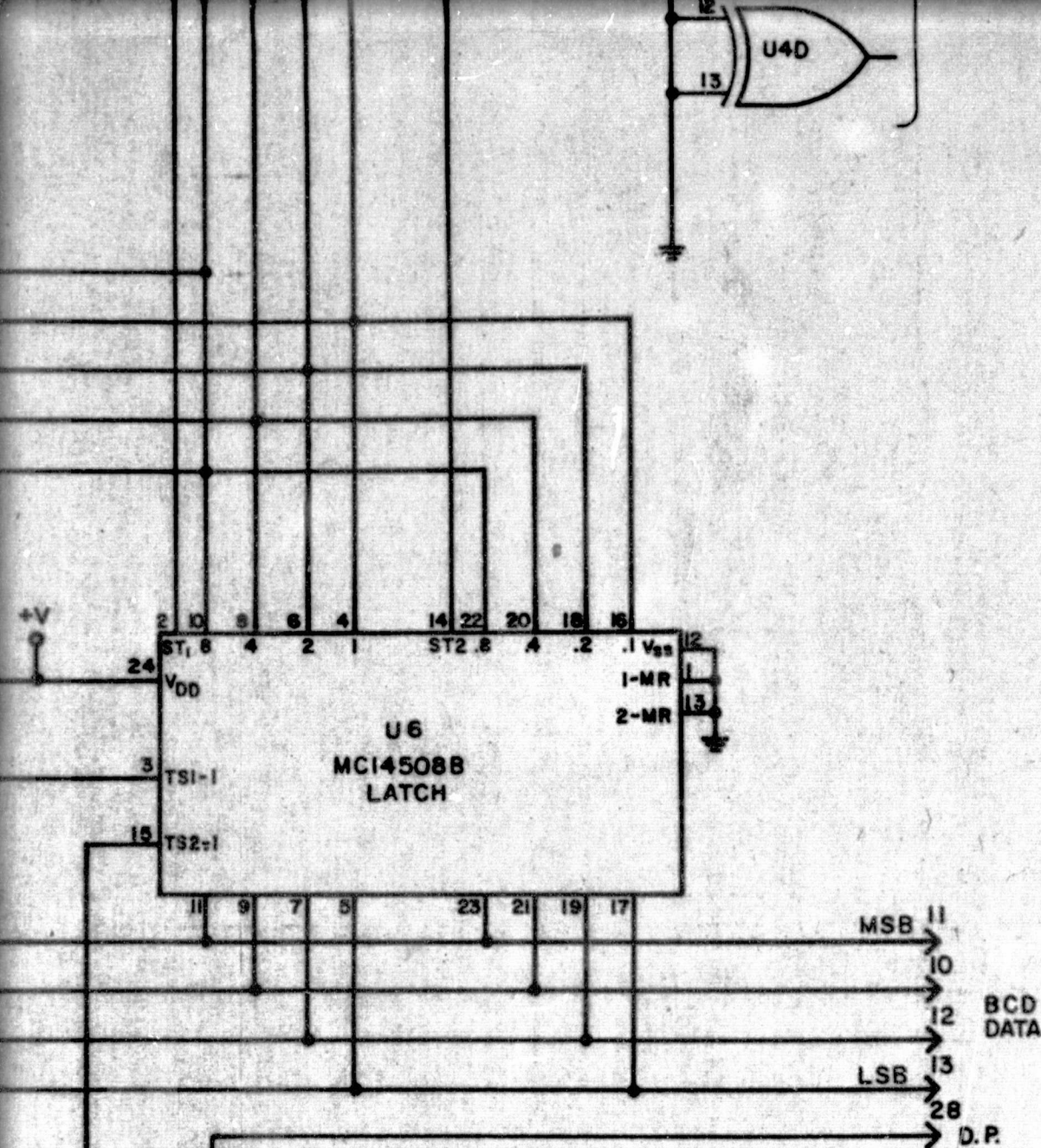
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22 20 18 16
23 24 25 26 27 28
20261 PKG.
TOP VIEW
1 2 3 4 5 6 7 8 9 10

DO NOT SCALE

UNLESS OTHERWISE SPECIFIED
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	MATERIAL					
	SIGNATURE	ORIGINATED	DRAWN	CHECKED	APPROVED	SCALE
DATE	7-28-77	7-28-77				
DENVER RESEARCH INSTITUTE UNIVERSITY of DENVER					EC-13269	

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BCD2
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BCD8

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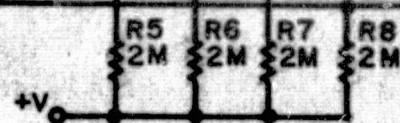
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U3E
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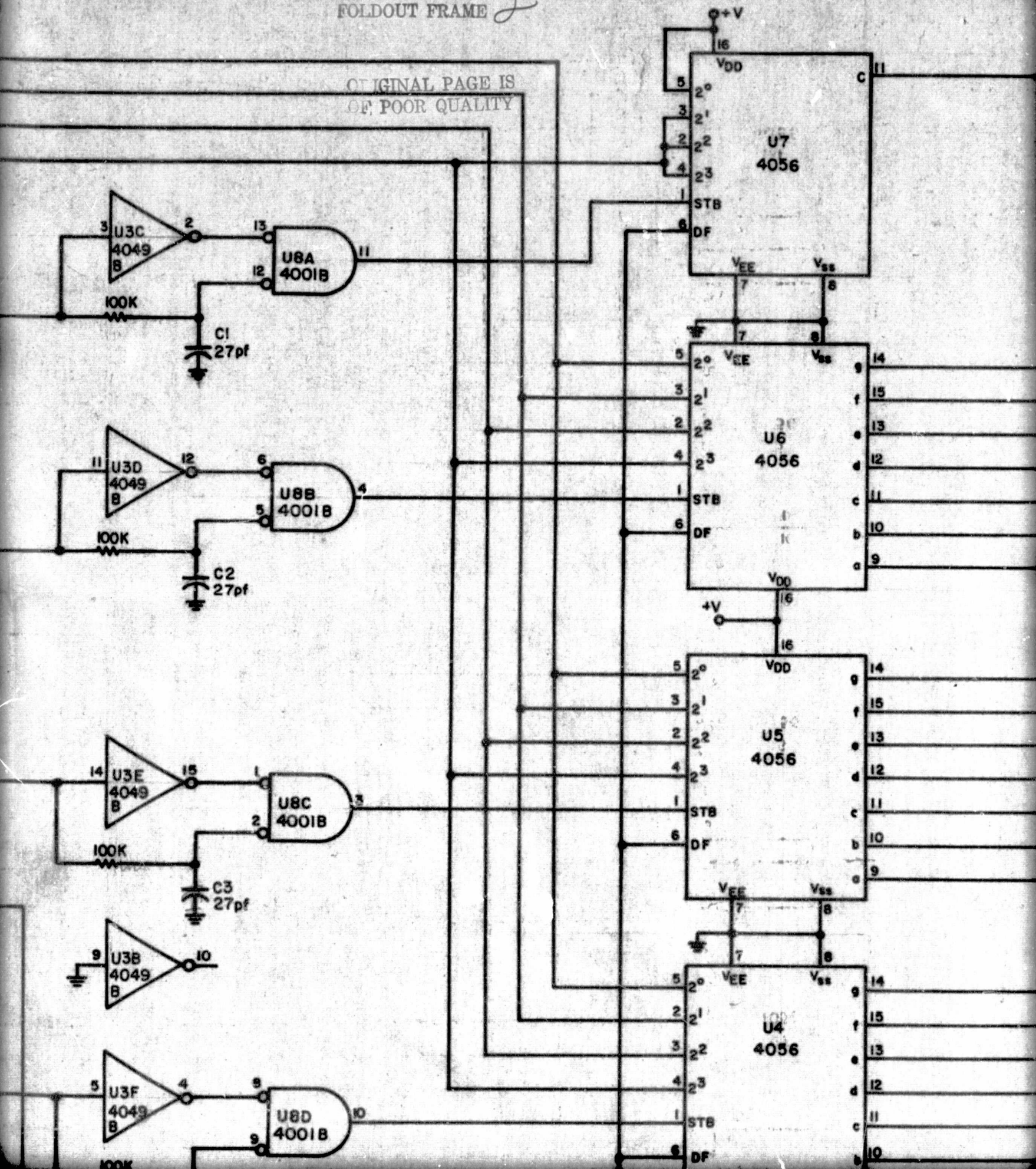
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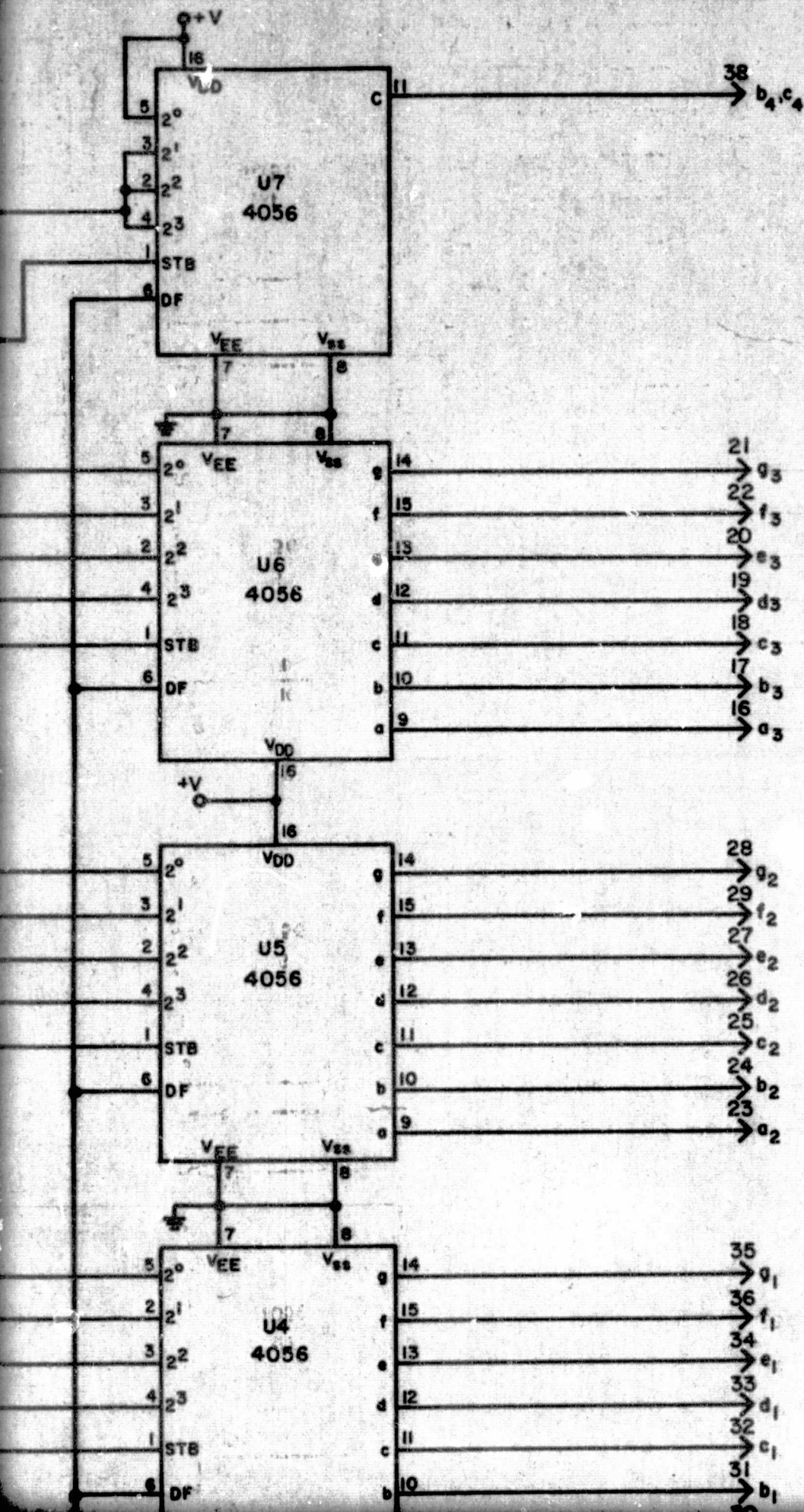


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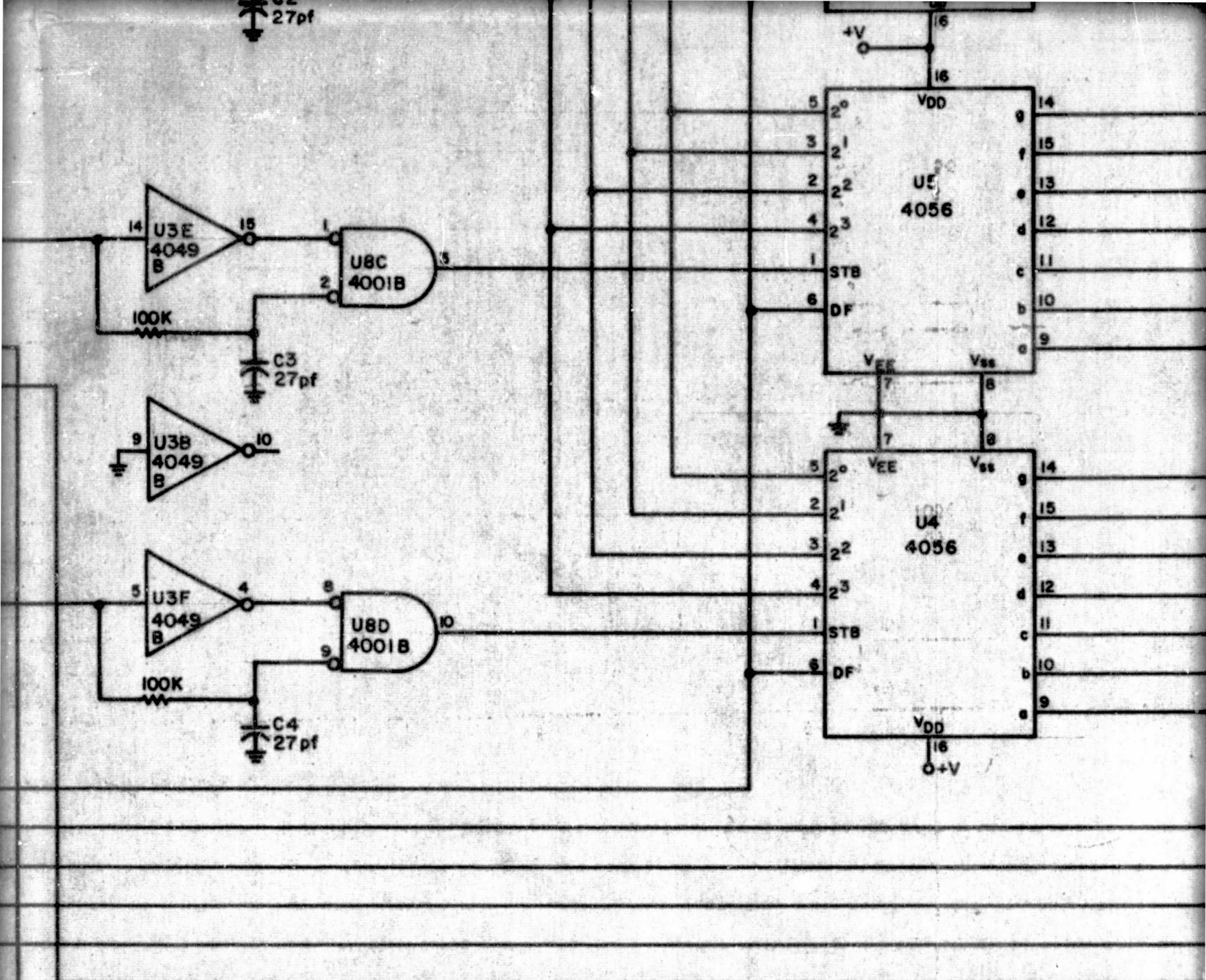
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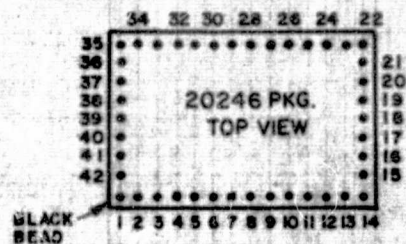
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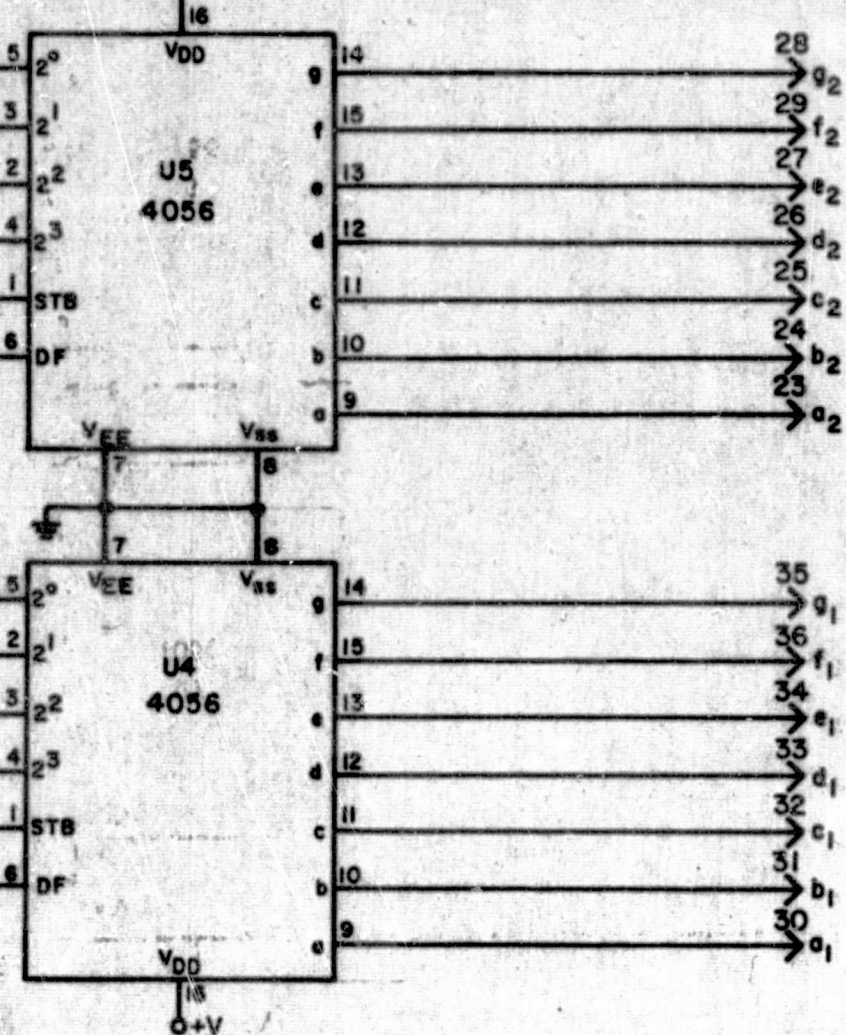


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- 6 DIGIT 1 SELECT
- 10 DIGIT 2 SELECT
- 9 DIGIT 3 SELECT
- 8 DIGIT 4 SELECT
- 7 DISPLAY SELECT 1
- 6 DISPLAY SELECT 2
- 4 DISPLAY SELECT 3
- 5 DISPLAY SELECT 4

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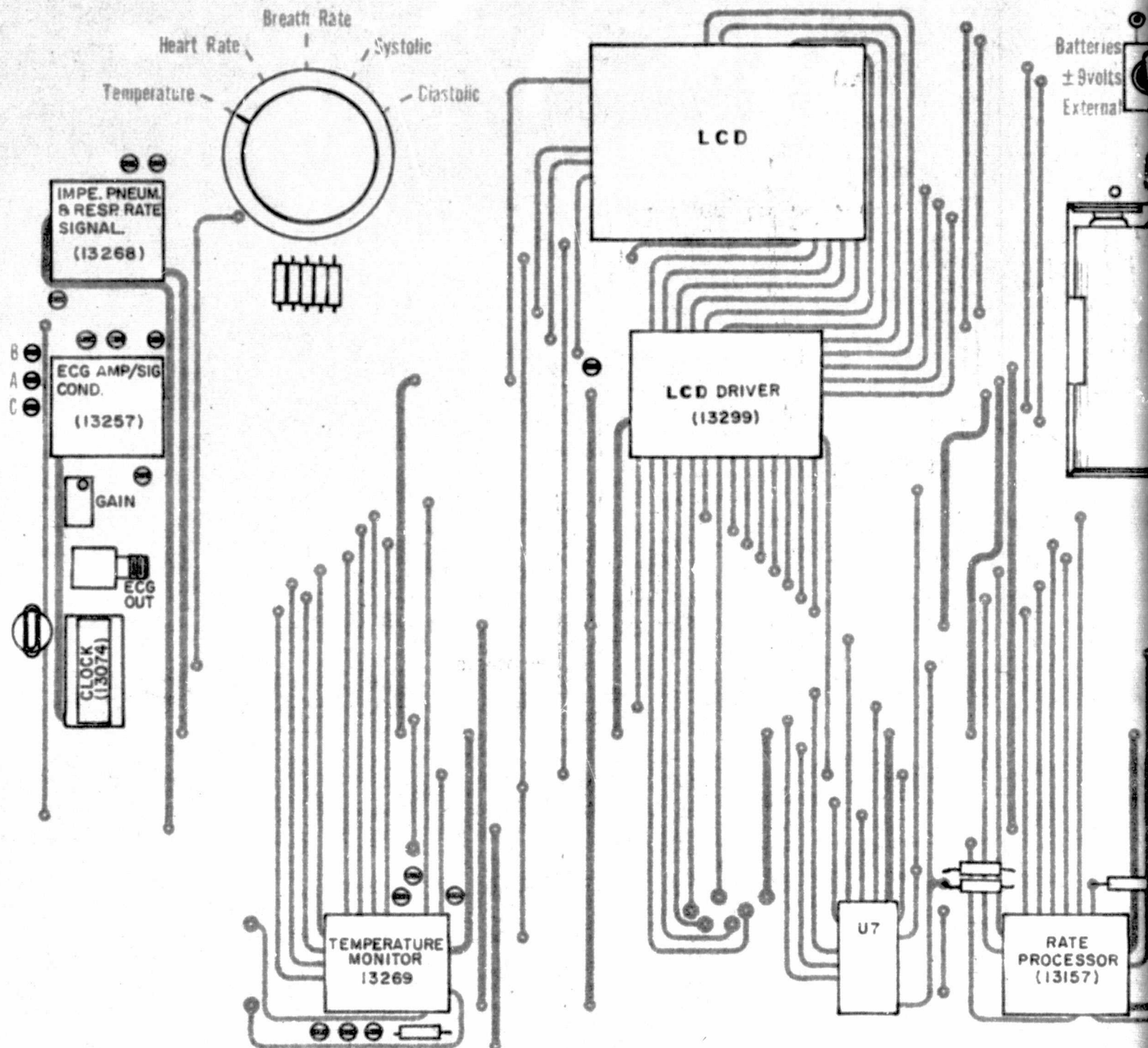
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	FINISH			MATERIAL		
	SIGNATURE	ORIGINATED	DRAWN	CHECKED	APPROVED	SCALE
	DATE		11-7-77			
DENVER RESEARCH INSTITUTE UNIVERSITY of DENVER				EC-13299		

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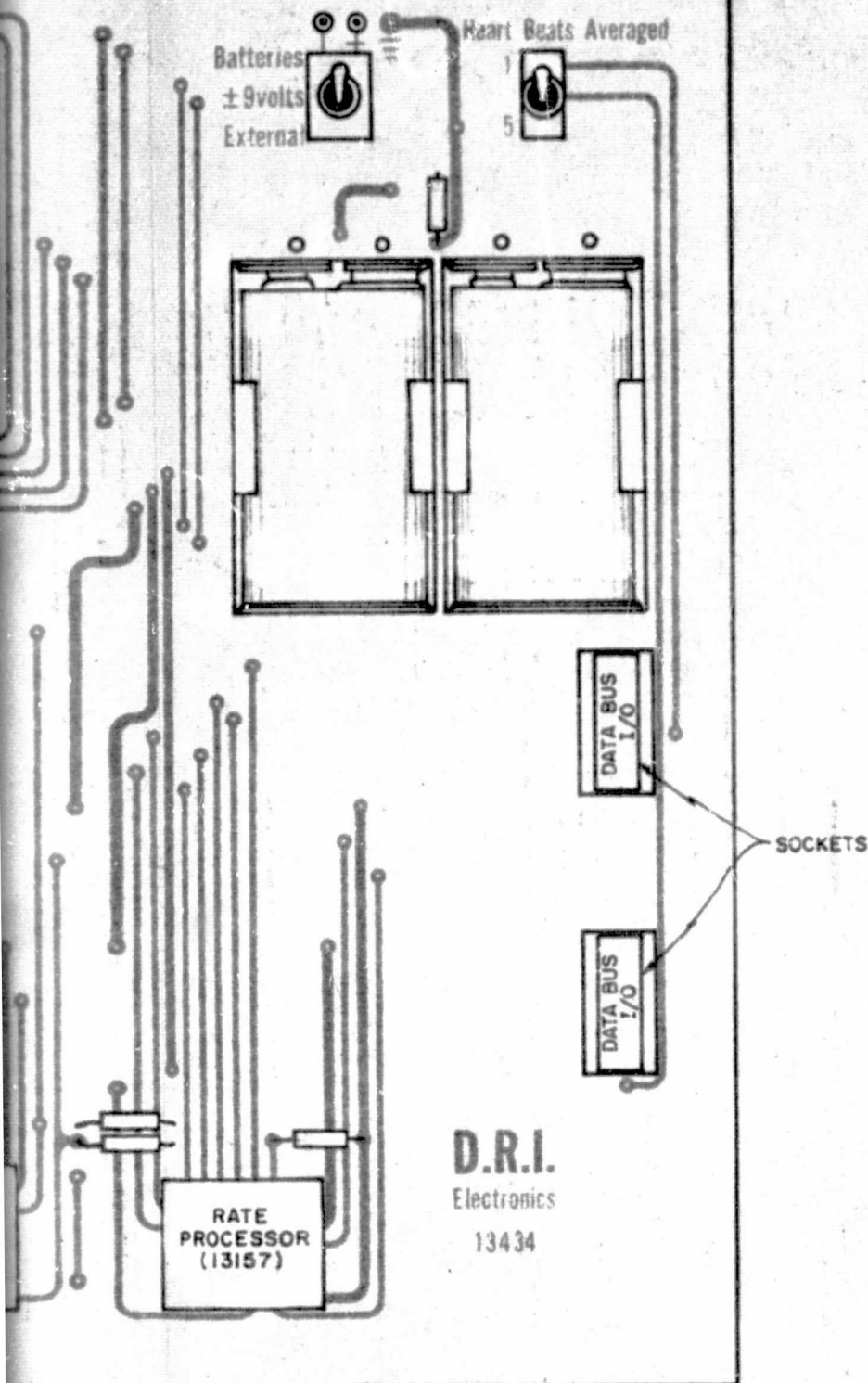
FOLDOUT FRAME

Batteries
 ± 9 volts
External



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D.R.I.
Electronics
13434

UNLESS OTHERWISE SPECIFIED
ALL DIMENSIONS ARE IN INCHES
FRACTIONAL DIMENSIONS
DECIMAL DIMENSIONS
ANGULAR DIMENSIONS
FINISH

VITAL SIGNS MONITOR

MATERIAL

SIGNATURE

DATE

DESIGNED BY

DATE

CHECKED

APPROVED

SCALE

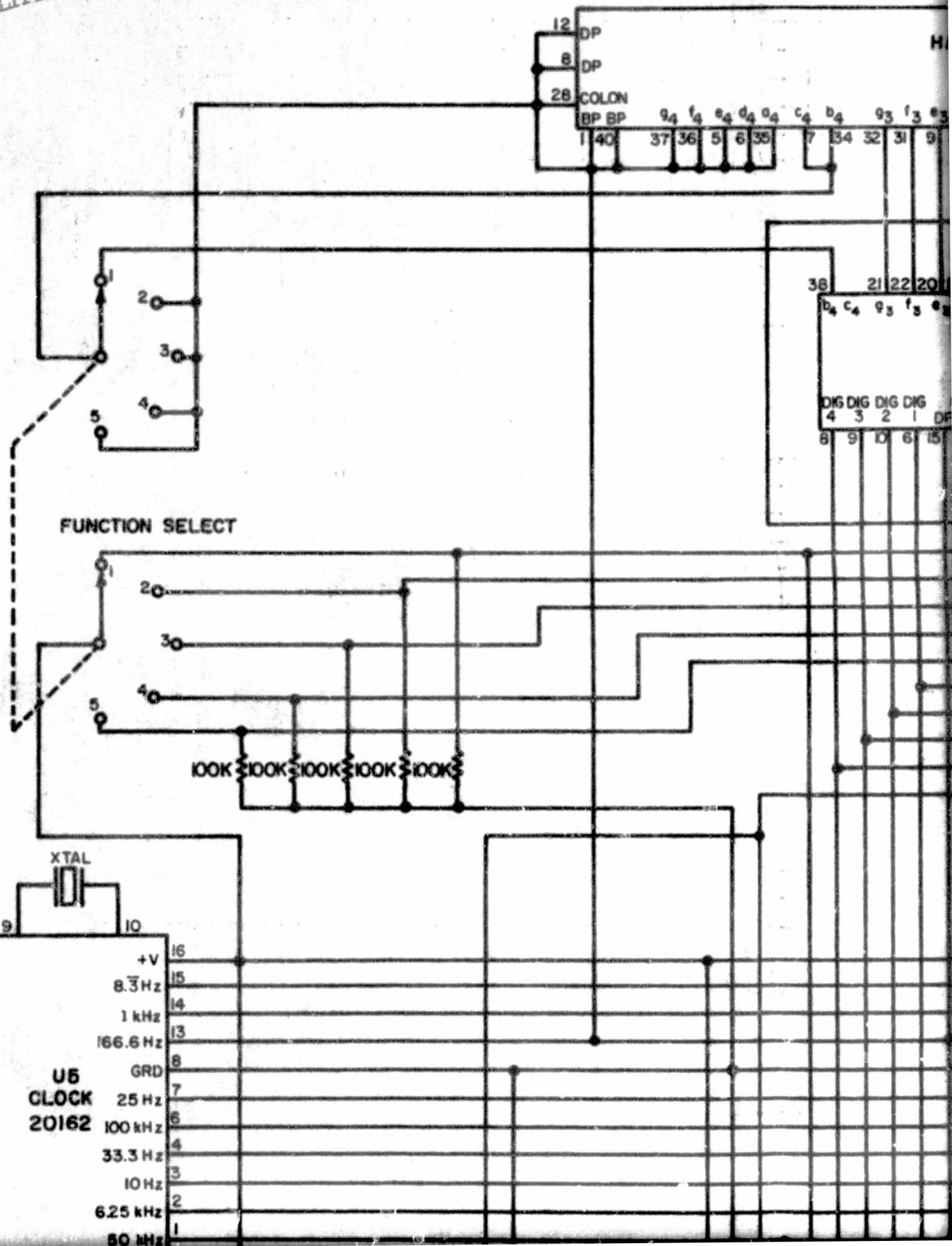
Week
3-9-77

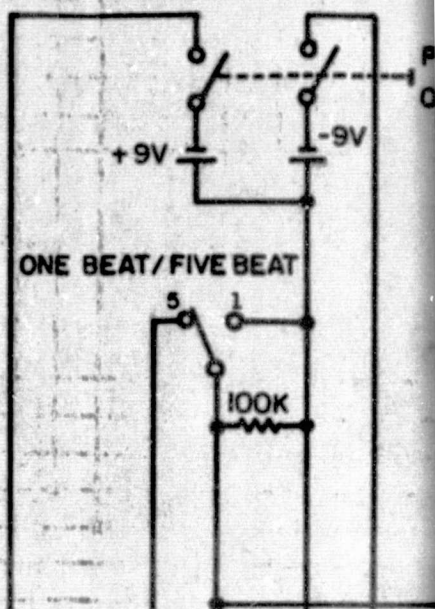
DENVER RESEARCH INSTITUTE
UNIVERSITY of DENVER

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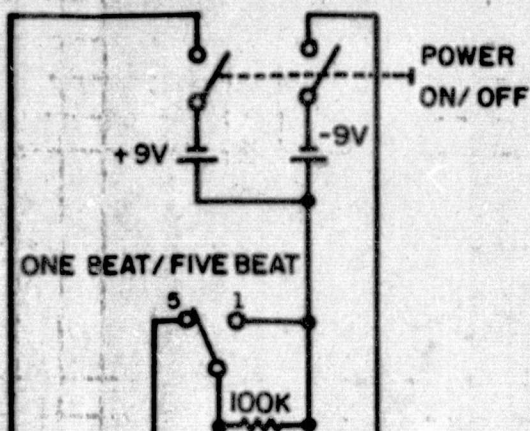
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B-1 HEARTBEAT AVG. SELECT.
 B-13 DECIMAL POINT
 A-8 FCT 1 (TEMP)
 A-4 FCT 2 (HEART)
 A-7 FCT 3 (BREATH)
 A-6 FCT 4 (SYSTOLIC)
 A-5 FCT 5 (DIASTOLIC)
 A-9 DIGIT 1 SELECT
 A-12 DIGIT 2 SELECT
 A-11 DIGIT 3 SELECT
 A-10 DIGIT 4 SELECT
 B-16 -V

B-9 +V
 B-10 8.3 Hz
 B-11 1 kHz
 B-12 166.6 Hz
 A-1 GRD
 A-2 25 Hz
 A-3 100 kHz
 B-5 33.3 Hz
 B-6 10 Hz
 B-7 6.25 kHz
 B-8 50 kHz
 A-15 BCD 1

FUNCTION SELECT

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6

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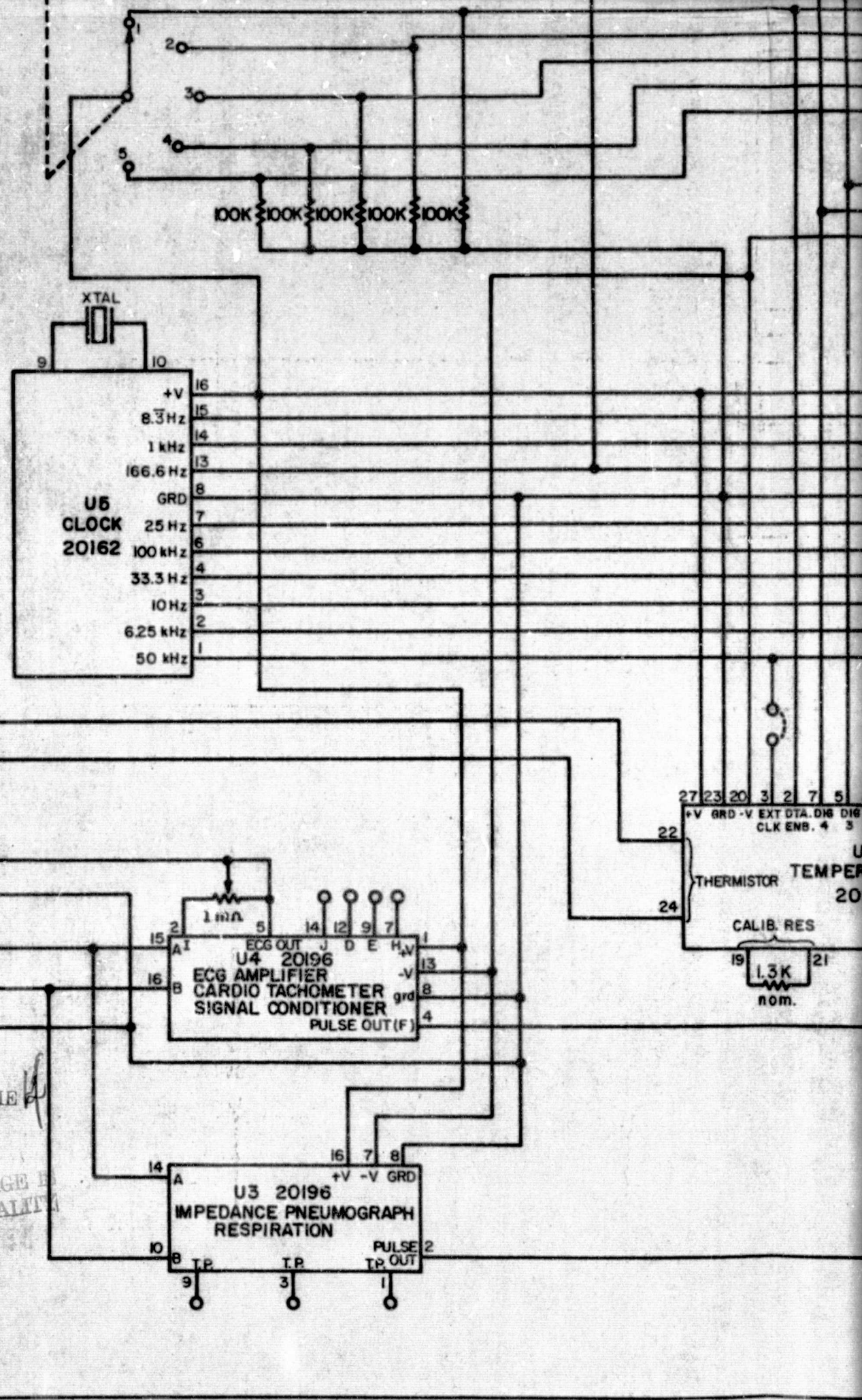
THERMISTOR CONNECTOR

ELECTRODE CONNECTOR

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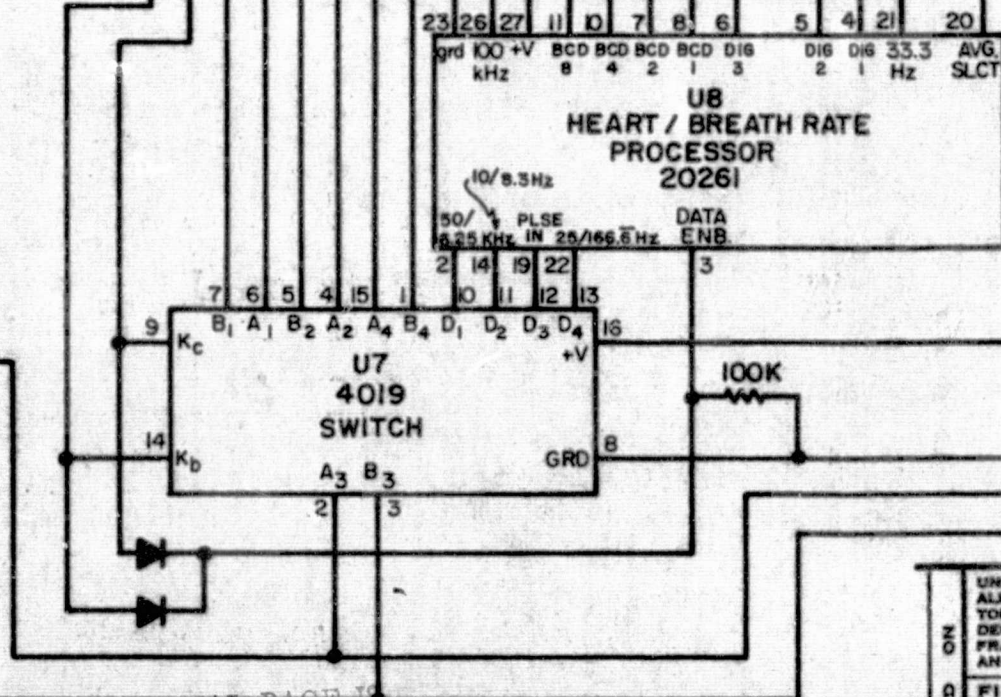
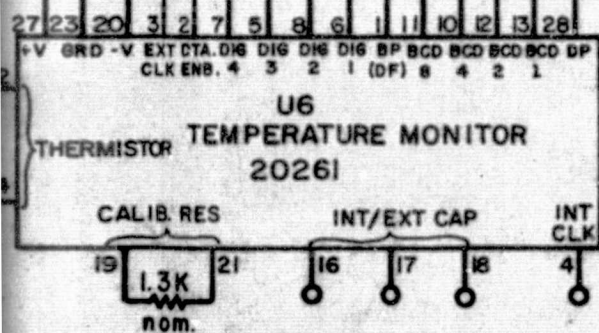


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		DENVER UNIVERSITY

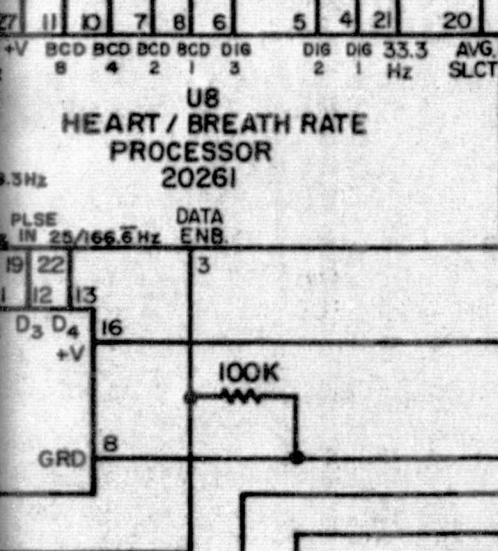
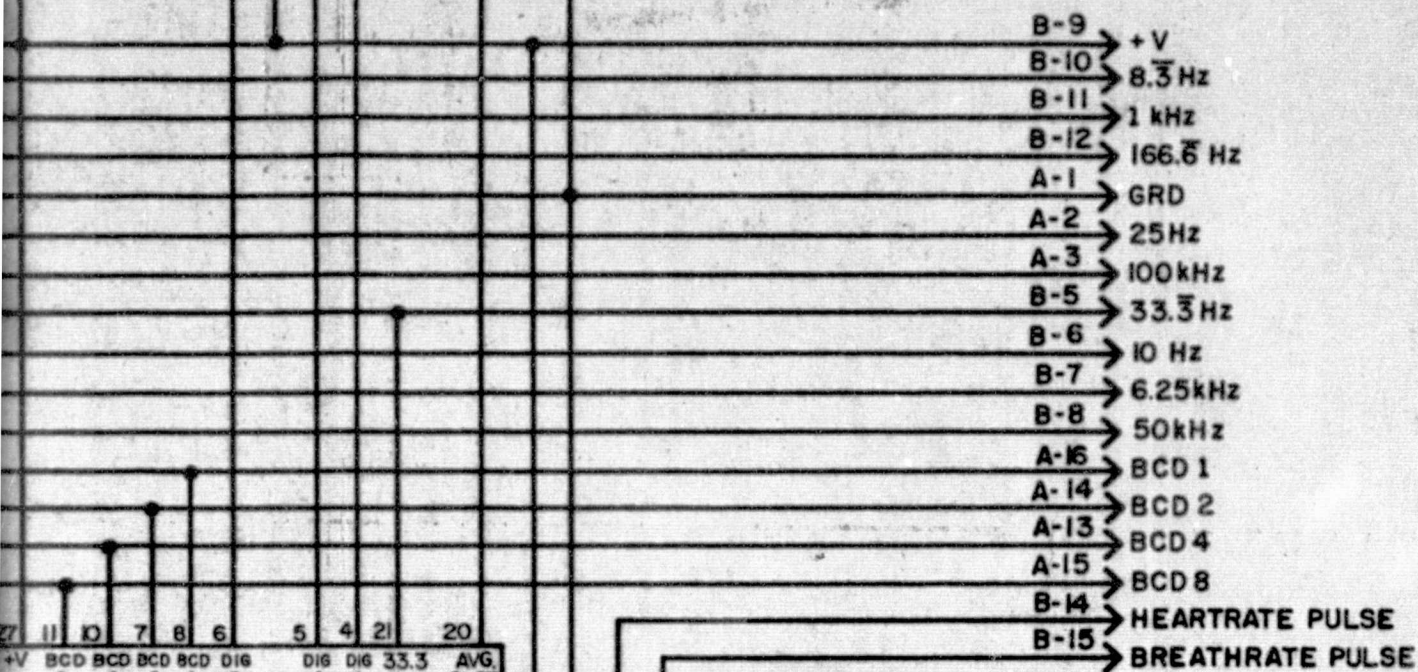
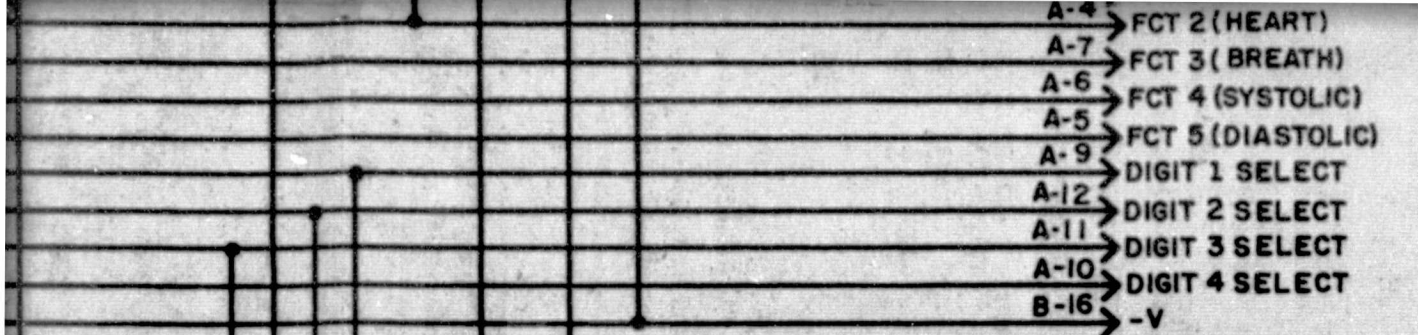
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DENVER RESEARCH INSTITUTE UNIVERSITY of DENVER			EC-13578				

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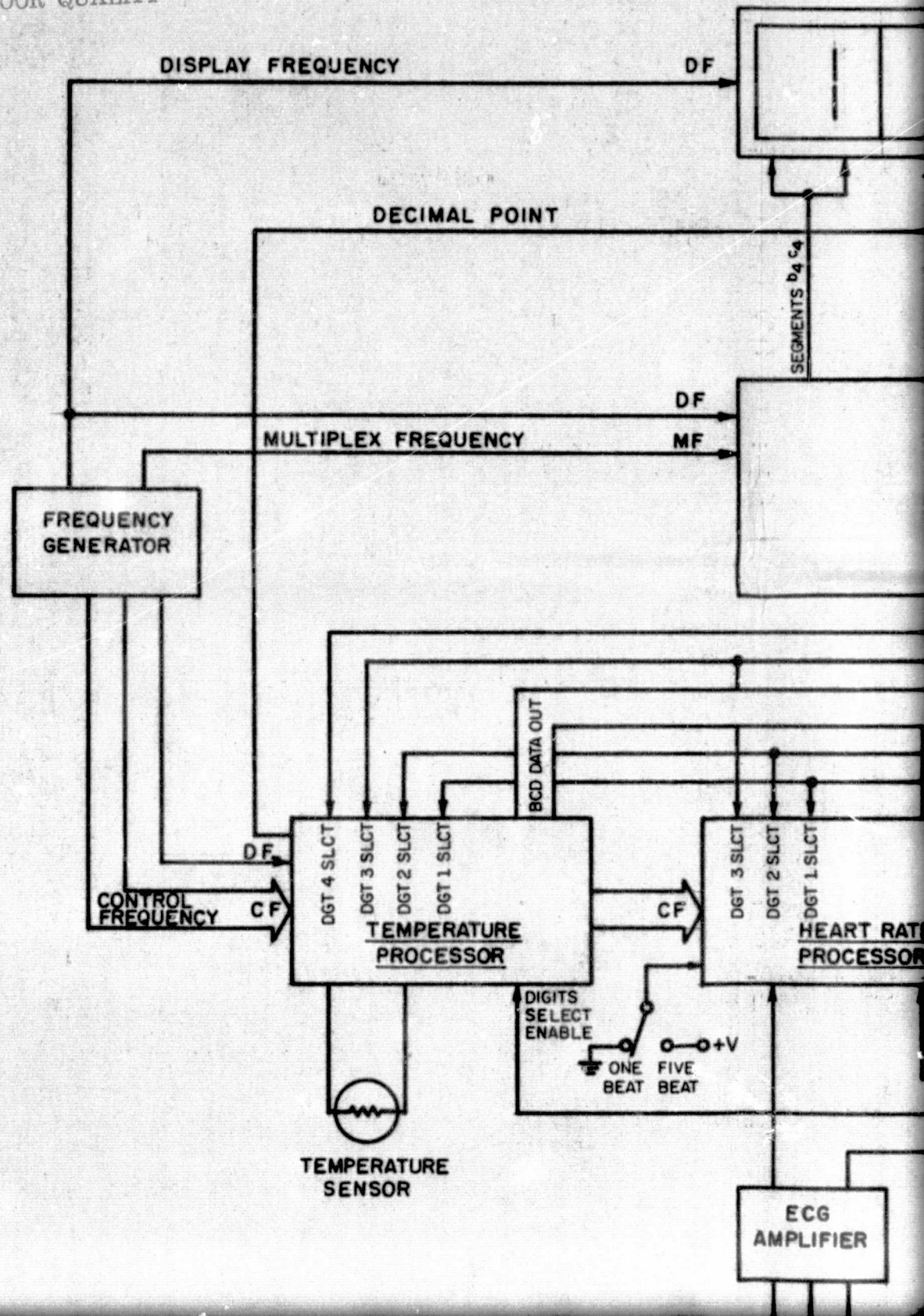
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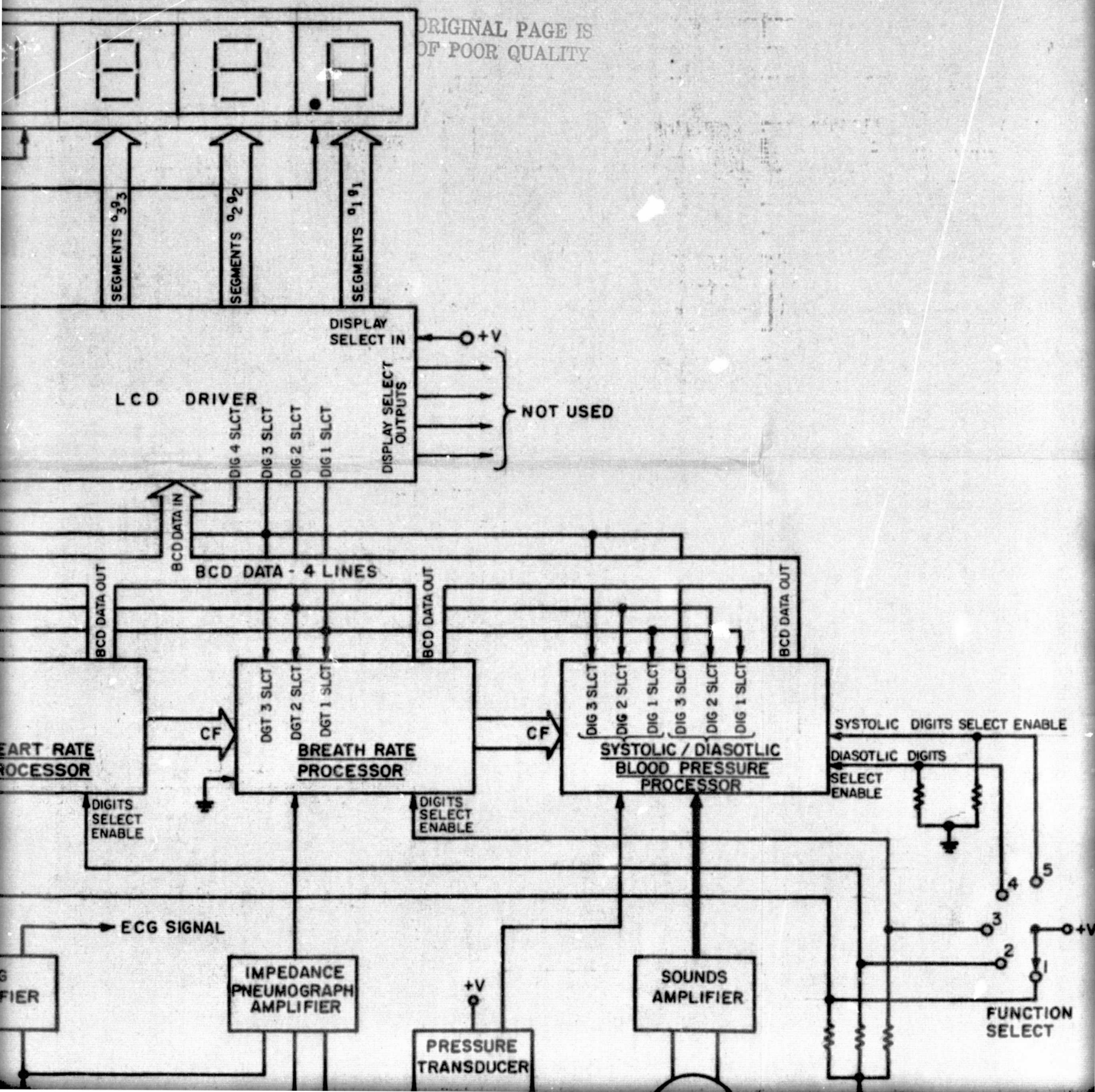
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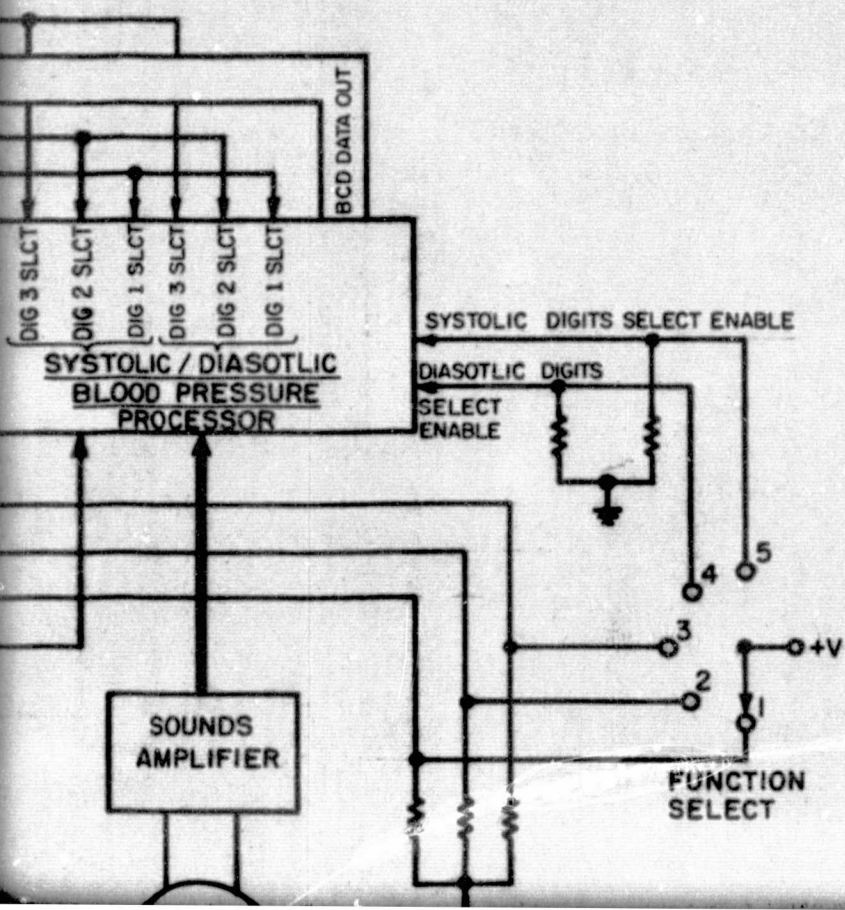
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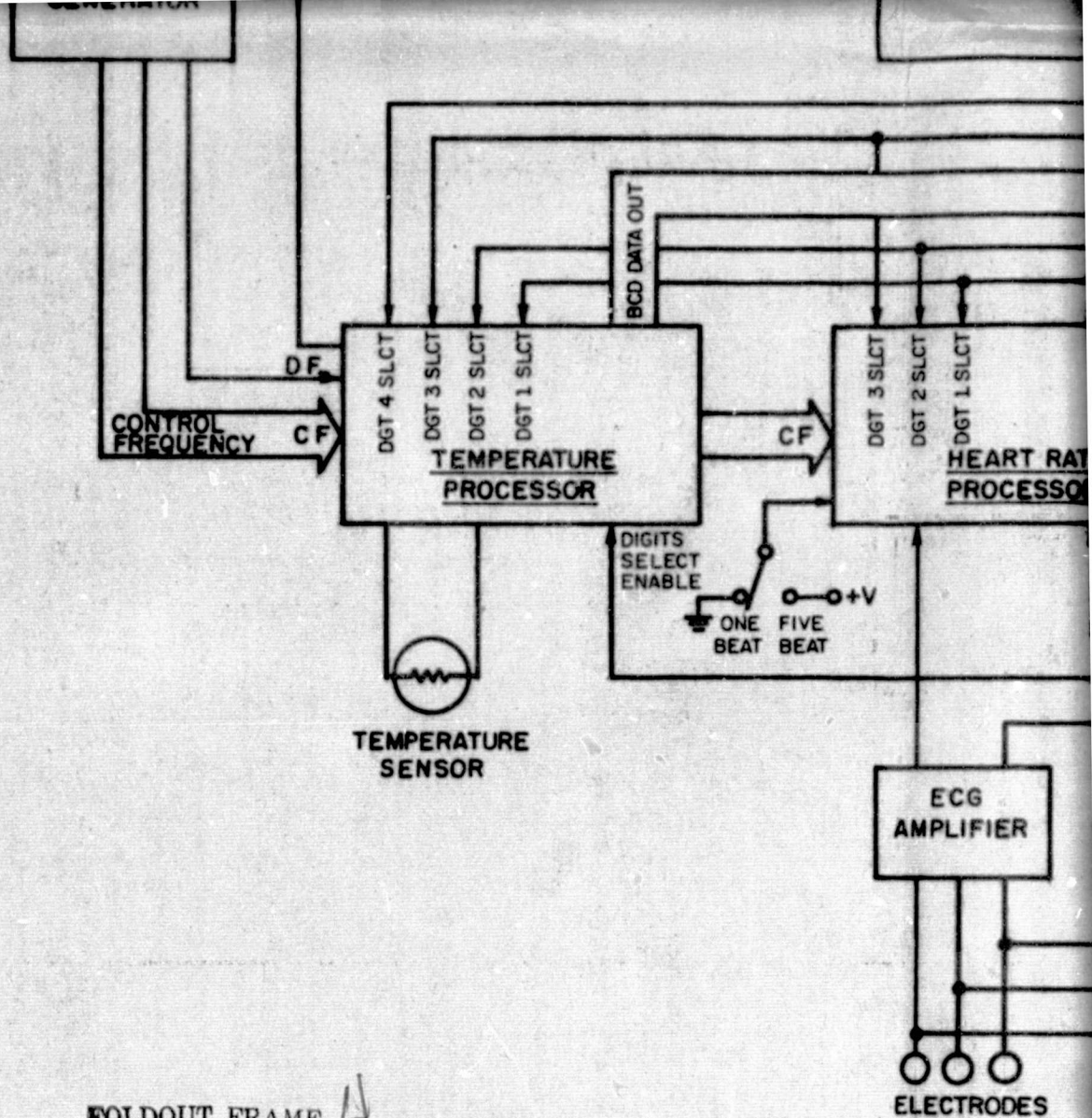
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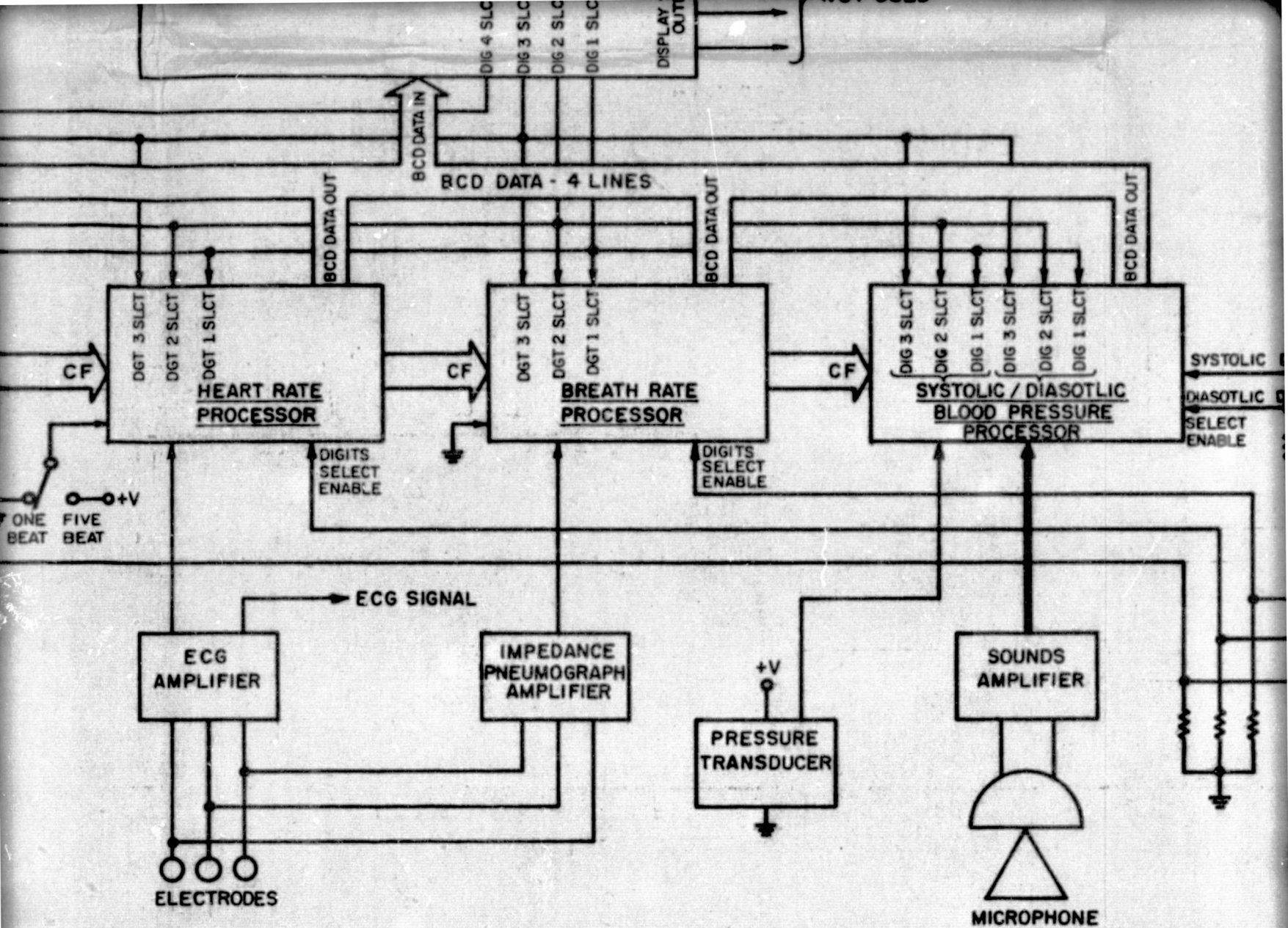
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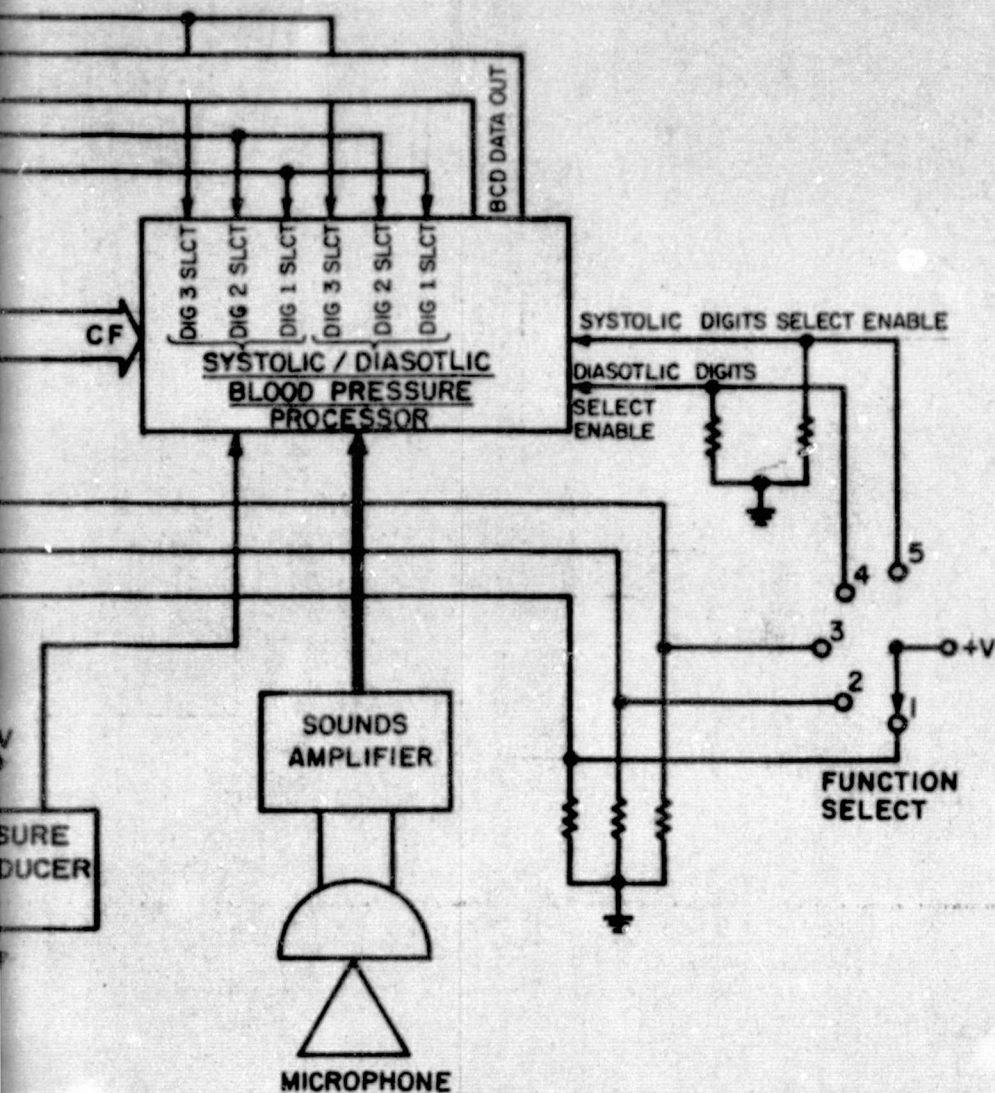
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UNLESS OTHERWISE SPECIFIED: ALL DIMENSIONS ARE IN INCHES TOLERANCE SHALL BE— DECIMAL DIMENSIONS ± FRACTION DIMENSIONS ± ANGULAR DIMENSIONS ±	TITLE VITAL SIGNS DIAGRAM FOR 4 DIGIT- LIQUID CRYSTAL DISPLAY																						
	MATERIAL																						
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SIGNATURE	ORIGINATED	DRAWN	CHECKED	APPROVED	SCALE																		
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APPENDIX C

Acceptance Test Records

ECG ACCEPTANCE TEST RECORD

Serial #		Test Date	
Parameter	Specification limit	Measured value	
A. Differential Gain	40 ± 1 db		
B. Common Mode Gain	-50 db min		
C. Input Amp dc offset	less than $\pm$ /volt at room temp.		
D. Input Impedance Differential	less than 180 mv = > 40 megohms		
E. ECG Amplifier Output d.c. offset	less than ± 0.25 v at room temp.		
F. ECG Amplifier Maximum Overall Gain & Sinewave Fidelity	less than 2.2 mv peak to peak, A = 4500 1% distortion max.		
G. ECG Minimum Overall Gain	Greater than 16 mv peak to peak, A = 625		
H. Output Noise Referred to Input	Less than 10 microvolts		
I. ECG Amplifier Frequency Response 0.14 Hz to 35 Hz	total spread less than 1 db		
0.05 Hz & 100 Hz with res- pect to 2 Hz	-3 db ± 1 db		
J. ECG Amplifier Output Impedance	The output must not be reduced to less than half when the 200 Ω load is applied		
K. ACG Output Amplitude			
1. Diff. Input A +AGC Output -AGC Output	2 ± 0.1 volts for all conditions		
2. Diff. Input B +AGC Output -AGC Output			
L. Cardiotachometer Signal Conditioner Output Amplitude duration	7.5 volts 100 ± 15 ms		

Impedance Pneumograph Acceptance Test Record

Serial #

Test Date

Parameter	Specification limit	Measured value
A. Excitation - Terminal A		
Waveshape	Triangular	
Amplitude	Approx 10 volts p to p	
Frequency	50 ± 5 kHz	
Excitation - Terminal B		
Waveshape	Triangular	
Amplitude	Approx 10 volts p to p	
Frequency	50 ± 50 kHz	
B. Excitation Current		
Terminal B		
Waveshape	Approx square	
Zero to peak positive	0.25 volt max.	
Zero to peak negative	0.25 volt max.	
Terminal A	Same specification as Terminal B	
C. Differential Amp & Rectifier		
Output dc level-input shorted	+0.3 volts max	
Output dc level - input 1K	Typicall 2.3 volts	
Difference	2.0 volts min.	
D. Pneumograph Amplifier		
Output dc offset	± 2 volts min.	
Gain	$200 \pm 10\%$	
Upper - 3 db frequency	10 ± 1 Hz	
E. One Hertz Low Pass Filter & dc restorer		
Gain at 0.3 Hz	$0.9 \pm 10\%$	
Upper -3 db frequency	1.0 ± 0.1 Hz	
Lower -3 db frequency	0.09 ± 0.01 Hz	
Positive peak limiting	0.7 ± 0.1 volt	
Negative peak limiting	0.6 ± 0.1 volt	
F. Pulse Out to Respiration Rate Counter		
Pulse high state	7.5 volts min	
Pulse low state	0.1 ± 0.1 volts	

APPENDIX D

Caution Statement

CAUTION

STATIC PROTECTION REQUIRED

THE MOS DEVICES USED IN THESE CIRCUITS CAN BE DAMAGED BY STATIC DISCHARGES. HANDLE THIS PART ON CONDUCTIVE WORK STATION ONLY WITH PROPERLY GROUNDED TOOLS.

KEEP CIRCUIT IN CONDUCTIVE FOAM WHEN NOT IN USE.

BEFORE REMOVING FROM FOAM, OPERATOR SHOULD TOUCH THE FOAM AND CIRCUIT GROUND SIMULTANEOUSLY, THEN REMOVE CIRCUIT FROM FOAM AND INSERT INTO SOCKET. KEEP AWAY FROM SOURCES OF HIGHER VOLTAGE OR STATIC ELECTRICITY.

REFER TO RCA APPLICATION NOTE: ICAN-6000.

USE ONLY LOW INSERTION FORCE SOCKETS

EXCESSIVE FORCE REQUIRED TO INSERT HYBRID PACKAGES INTO SOCKETS CAN DISTORT THE PACKAGE AND DAMAGE THE CIRCUIT INSIDE.

EXCESSIVE FORCE ON PINS CAN BREAK GLASS TO METAL SEAL.

OBSERVE BATTERY POLARITY

REVERSE POLARITY WILL DAMAGE THE CIRCUITS.

PIN NUMBERING

FROM A TOP VIEW WITH PRINTING UPRIGHT PIN NO. 1 IS IN THE LOWER LEFT HAND CORNER. A DOT MARKS THIS CORNER. THE PINS ARE NUMBERED SEQUENTIALLY COUNTER CLOCKWISE FROM NO. 1. AS VIEWED FROM THE TOP.

(CAUTION: DISREGARD ANY PIN MARKINGS ON BOTTOM OF PACKAGE.)